HANDBOOK

WATER RESOURCE DATA

NEZPERCE NATIONAL FOREST

NORTHERN REGION

FOREST SERVICE

USDA

SECTION I

VEGETATION MANIPULATION GUIDELINES

for the

NEZPERCE NATIONAL FOREST

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INTRODUCTION

The materials and information presented in Section I, concerning vegetative manipulation and subsequent effects on water yield represent the current state-of-the-art in Region One. Much of what follows is an incorporation of data and research work done by other hydrologists within as well as outside of the Region, with pertinent adaptations to the Nezperce area.

Research is continuing in the area of watershed hydrology, and is oriented to provide more specific data and procedures for quantifying the effects of road construction and timber harvest on the water yield. While research is progressing towards completion, the Resource Manager, by necessity, must utilize the best information now available in order to satisfy present requirements for resource protection and development planning.

The techniques, procedures, and guidelines herein described are purposefully designed for use by the field forester as an interim tool to assess present and future development impacts on the water resource. In addition, they will provide a basis for the timely and proper consideration of the primary water resource management objectives of watershed, drainage channel, and water quality protection. It will become apparent with the use of the procedures, guides, and recovery programming techniques that there is available to the Resource Manager a wide range of development alternatives when considering treatment of watershed vegetation.

Thus, the purpose of these guides is to create an awareness with the Resource Manager of the nearly unlimited potential for developing the optimum management situation; wherein the timber and water resources of a particular watershed can be managed so as to maximize the timber development on a sustained basis and still maintain a favorable hydrologic response for an indefinite time period.

PART I

Basic Water Resource Inventory Procedures and Estimating Average Annual Water Yields Before Treatment.

Discussion

The Nezperce water yield estimating procedures and timber cutting guidelines are based on a water balance approach to estimate increases in water yield due to vegetative manipulation. A general water balance equation would read as Q=P-ET; where Q=Ave. annual runoff, P=Ave. annual precipitation, and ET = evapotranspiration losses. The use of these procedures requires a quantitative data input which is of a quality sufficient for making valid and logical estimates and extrapolations.

For a given area, if the values for precipitation and evapotranspiration are known or can be reasonably estimated, the value for "Q", or runoff, can be calculated. Once the average annual runoff data is available, increases in runoff due to removal of vegetation may be estimated through further refinements in the water balance technique. In the case of the Nezperce, a "water yield increase factor" has been developed which partially takes into account the ET portion of the general water balance equation. The variation of this factor with elevation for the Nezperce area in shown in Figure 12. Runoff data for the entire Forest is now available as a water yield atlas for each District; developed from the ARS publication, "Water Yield Maps for Idaho." Figure 13 entitled Precipitation versus Runoff - Water Yield provides a means of estimating runoff for an area when only precipitation is known, or vice versa.

Thus, there is available at the present time a significant amount of hydromet information that can be effectively used to develop an estimate of the effects of vegetative treatment on local watershed hydrology.

Procedures

1. Prepare a base map of the area suitable for use with overlays, to present graphically the necessary water resource data. The most appropriate map appears to be the standard USGS topographic map, 1/24,000 scale, 7½ minute quad, at 2.65"/mile. In the case of some area plans, use of this type map reduced to a scale of 2"/mile would be suitable. Establish the primary area boundary (solid line).

   a. Delineate all stream channels not shown on the topog map, that are within the drainage area, with a 3 or 4H pencil; using the topographic contours as a reference. A drainage channel is considered to exist as long as there is a distinct indentation or "V" in the contour line. See Figure 5 for example.

   b. On a suitable overlay material, using a color code, determine the "order" of all stream channels that make up the drainage network. See Figures 1 and 6 for ordering procedures and sample overlay.

FIGURE 1 - Determining Stream Orders.

Stream order is a term used to characterize the branching of a drainage. A first order stream is any mapable, unbranched tributary. A second order stream is formed when two unbranched first order channels join together; and continues as a second order stream until it meets another second order channel to become a third order channel; or enters a third order or higher channel as a side drainage. A second order channel may have any number of first order channels entering along its length, just as a third order channel may have several second order channels entering from the side, etc.

	Blackline Code	Color Code
First Order	1	Red
Second Order	2	Blue
Third Order	3	Green
Fourth Order	4	Brown
Fifth Order	5	Orange
Sixth Order	6	Purple

c. On the base map and using the stream order overlay for reference, delineate subdrainage boundaries (dashed line). For practical use with these procedures, subdrainages should be:

- at least a 3rd, 4th, and in some cases a 5th order stream or drainage

- an "entity," that is a closed drainage or one that does not include the small "interior" or "front-facing" drainages.

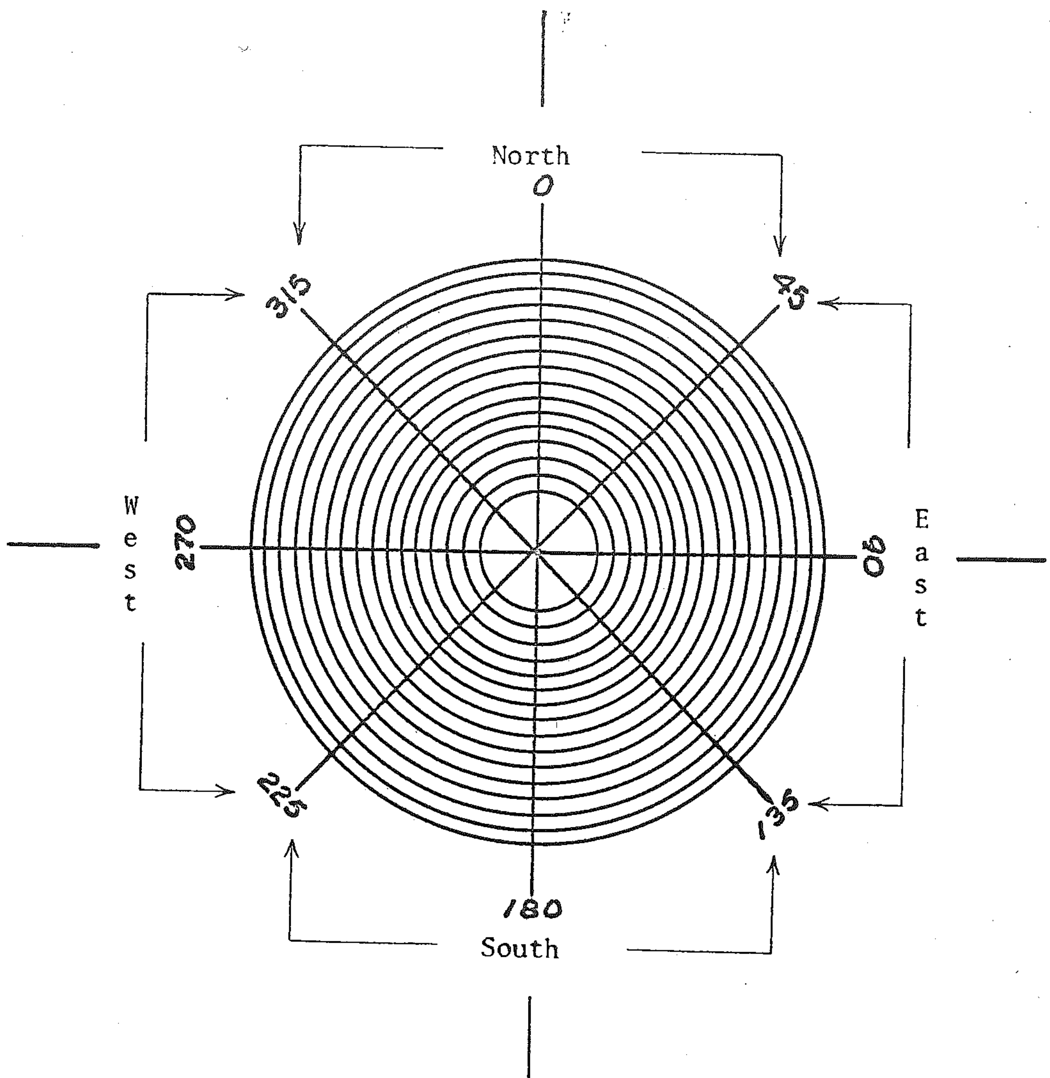
An example of a "front-facing" drainage area would be one that has its lower boundary a length of 5th or 6th order channel and is drained by 1st order streams. Determine the area of each subdrainage and the total drainage area and tabularize for use in the following data tables.

d. If these procedures are being applied to an area plan analysis, the following information can be important as a portion of the total resource inventory.

(1) Determine the number of channels by order, and the total mileage of each order; by subdrainage. Assemble this data in tabular form similar to Table 1.

(2) Construct a general aspect overlay depicting the drainage area in terms of "aspect units." Delineation of a subdrainage into aspect units is done with reference to the topographic contour, a Nezperce Aspect Grid (Fig. 2), and the use of an 'eyeball' technique.

FIGURE 2 . Nezperce Aspect Grid.



Using the grid as a visual reference, delineate aspect units on an overlay for the topog base map. The concentric circles represent **idealized** contour lines, with north slopes considered as the area between 315° and 45°; east slopes between 45° and 135°; south slopes between 135° and 225°; and west slopes between 225° and 315°.

Generally stated, an aspect unit is a land unit that is oriented either northerly, southerly, easterly, or westerly with respect to visual reference and the local topography. Determine the total area for each aspect by subdrainage and assemble as in Table 2. Figure 7 is a sample aspect overlay.

e. Delineate the elevation zones within the drainage area using the primary elevation contours, in increments of 1,000 feet. Suggest using an orange or brown nylon pen for outlining contours. Determine the area of each elevation zone by subdrainage and assemble the data in a form similar to Table 3.

2. Collect published U.S. Geological Survey, Agricultural Research Service, U. S. Weather Bureau, and Soil Conservation Service data where available concerning precipitation, water yield, snow surveys, etc. From these data it is possible to construct average annual precipitation and water yield overlays. In the case of the Nezperce Forest, all water yield overlays are based on the ARS publication, "Water Yield Maps for Idaho - ARS 41-141 - Mar. 1968." A ½"/mi. scale map showing the average annual water yield isolines as taken from the ARS maps will be developed and furnished to each District.

a. Using the available water yield maps, transpose or fit the water yield lines or contours, called "isolines," to the drainage area base map. Available short term precipitation or runoff records may be used to assist in adjusting the isolines from the smaller scale map to the local terrain on your larger base map. This data is best depicted on an overlay. See Figure 8.

b. After completing the water yield overlay, planimeter the area between isolines for each water yield or inch-depth zone by subdrainage. The area between any two isolines is given a value equal to the average of the upper and lower isoline, i.e., the area between a 10-inch line and a 14-inch line is considered to yield an average of 12 inches of water per acre per year. Converting the average inch-depth isoline value to feet and multiplying the foot-depth value by the area between isolines provides a volume estimate in acre feet of water. Subsequent totals of isoline area volumes would be an estimate of the average annual runoff for the drainage or subdrainage.

c. Set up calculated water yield data in tabular form similar to Table 4.

3. After calculating the annual water yield for the subdrainage, determine monthly discharge or runoff in acre feet. Select water yield data for one or more stream gaging stations near the drainage under analysis. These data are available for all USGS stations and locally for Forest Service stations. A sample of USGS Water Supply Paper data is shown in Figure 3. A summary of the monthly water yields and monthly yield percentages for selected stations on the Nezperce Forest is shown in Table 5. Where this summary is not available or does not apply, proceed as follows:

a. Using the data for the nearest appropriate gaging station, i.e., the monthly recorded discharge in acre feet, determine the average monthly flow for the period of record, and the average annual yield.

b. Determine as a percentage what each average monthly yield is of the average annual yield. If more than one set of gaging station records is appropriate for use, the monthly percentage values of the two (or more) stations may be averaged to obtain an estimate to apply to the drainage area yield.

c. Using the average annual water yield estimate calculated for the drainage area, apply the average monthly yield percentages developed from gaging station data to find an estimate of monthly water yields for the drainage area. Assemble this data in a table as shown in Table 6.

d. Plot the monthly estimated water yields for the drainage or subdrainage area as a hydrograph shown in Figure 4.

FIGURE 3. Excerpt From USGS Water Supply Paper, 1737, for years 1951 through 1960.

3375. South Fork Clearwater River near Elk City, Idaho

Location.--Lat 45°49', long 115°32', in NE¼ sec.25, T.29 N., R.7 E., on right bank just upstream from bridge on road to Orogrande, 0.2 mile upstream from Crooked River, and 4½ miles west of Elk City.

Drainage area.--261 sq mi. Mean altitude, 5,150 ft.

Records available.--September 1944 to September 1960.

Gage.--Water-stage recorder. Datum of gage is 3,816.27 ft above mean sea level, datum of 1929, supplementary adjustment of 1947. Prior to June 23, 1949, wire-weight gage at site 24 ft downstream at datum 6.14 ft lower.

Average discharge.--16 years (1944-60), 262 cfs (189,700 acre-ft per year).

Extremes.--1944-60: Maximum discharge observed, 3,700 cfs May 29, 1948 (gage height, 13.06 ft, site and datum then in use); minimum daily, 10 cfs Nov. 28, 29, 1952.

Remarks.--No regulation or diversion above station except for mining operations. Records of water temperatures for the period July 1956 to September 1957 are published in reports of Geological Survey.

Monthly and yearly mean discharge, in cubic feet per second

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The year
1951	67.8	94.8	119	93.2	144	120	722	839	310	108	43.1	30.4	224
1952	78.1	67.3	74.0	66.5	71.8	110	880	1,279	402	117	42.6	27.9	268
1953	24.9	29.1	30.7	59.9	72.8	114	462	834	721	118	43.6	24.7	211
1954	29.7	45.7	49.5	45.5	59.9	93.4	553	603	453	144	66.5	42.9	182
1955	51.1	55.0	42.6	36.9	42.5	48.5	226	1,200	946	364	79.0	47.7	263
1956	62.3	109	112	101	71.4	179	1,016	1,271	431	126	59.8	38.7	298
1957	56.7	79.7	84.3	55.7	77.5	205	664	1,495	413	118	47.5	34.6	279
1958	49.9	43.7	48.3	43.8	91.2	106	503	825	446	168	54.7	47.1	202
1959	60.3	127	285	176	156	202	770	1,173	617	134	48.5	105	322
1960	263	231	163	98.8	76.3	225	853	951	411	88.3	57.7	39.7	288

Monthly and yearly discharge, in acre-feet

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The year
1951	4,170	5,640	7,320	5,730	7,980	7,380	42,960	51,570	18,450	6,660	2,650	1,810	162,300
1952	4,800	4,000	4,550	4,090	4,130	6,760	52,360	78,650	23,930	7,210	2,620	1,660	194,800
1953	1,530	1,730	1,890	3,690	4,040	7,000	27,490	51,300	42,900	7,280	2,680	1,470	153,000
1954	1,830	2,720	3,050	2,800	3,330	5,740	32,930	37,080	26,960	8,870	4,090	2,550	132,000
1955	3,140	3,270	2,620	2,270	2,360	2,990	13,470	73,770	56,320	22,370	4,860	2,840	190,300
1956	3,830	6,470	6,910	6,230	4,110	11,000	60,430	78,130	25,670	7,760	3,680	2,300	216,500
1957	3,490	4,740	5,180	3,420	4,310	12,600	39,530	91,930	24,580	7,230	2,920	2,060	202,000
1958	3,070	2,600	2,970	2,690	5,070	6,500	29,910	50,730	26,570	10,310	3,360	2,800	146,600
1959	3,710	7,580	17,500	10,850	8,690	12,440	45,840	72,150	36,740	8,250	2,980	6,230	233,000
1960	16,170	13,760	10,030	6,070	4,390	13,820	50,760	58,490	24,460	5,430	3,550	2,360	209,300
AVE	4575	5250	6200	4785	4840	8675	39550	64380	30660	9170	3340	2610	183980
%	2.5	2.9	3.4	2.6	2.6	4.6	21.5	35.0	16.7	5.0	1.8	1.4	–

Yearly discharge, in cubic feet per second

Year	WSP	Water year ending Sept. 30								Calendar year		
		Momentary maximum		Minimum day	Mean	Per square mile	Runoff			Mean	Runoff	
		Discharge	Date				Inches	Acre-feet			Inches	Acre-feet
1950	-	-	-	-	-	-	-	-		281	14.61	203,200
1951	1217	1,280	May 12, 1951	25	224	0.858	11.66	162,300		219	11.40	158,600
1952	1247	1,740	Apr. 28, 1952	23	268	1.03	14.01	194,800		257	13.41	186,600
1953	1287	1,460	Apr. 28, 1953	10	211	.808	10.99	153,000		215	11.17	155,500
1954	1347	1,180	May 10, 1954	22	182	.697	9.48	132,000		184	9.58	133,400
1955	1397	1,980	May 21, 1955	25	263	1.01	13.67	190,300		274	14.26	198,500
1956	1447	2,200	Apr. 23 or 24, 1956	31	298	1.14	15.55	216,500		293	15.27	212,700
1957	1517	2,120	May 21, 1957	27	279	1.07	14.51	202,000		272	14.17	197,200
1958	1567	1,690	Apr. 20, 1958	27	202	.774	10.52	146,600		230	11.97	166,700
1959	1637	1,770	May 16, 1959	34	322	1.23	16.72	233,000		337	17.52	244,100
1960	1717	1,660	Apr. 9, 1960	31	288	1.10	15.04	209,300		-	-	-

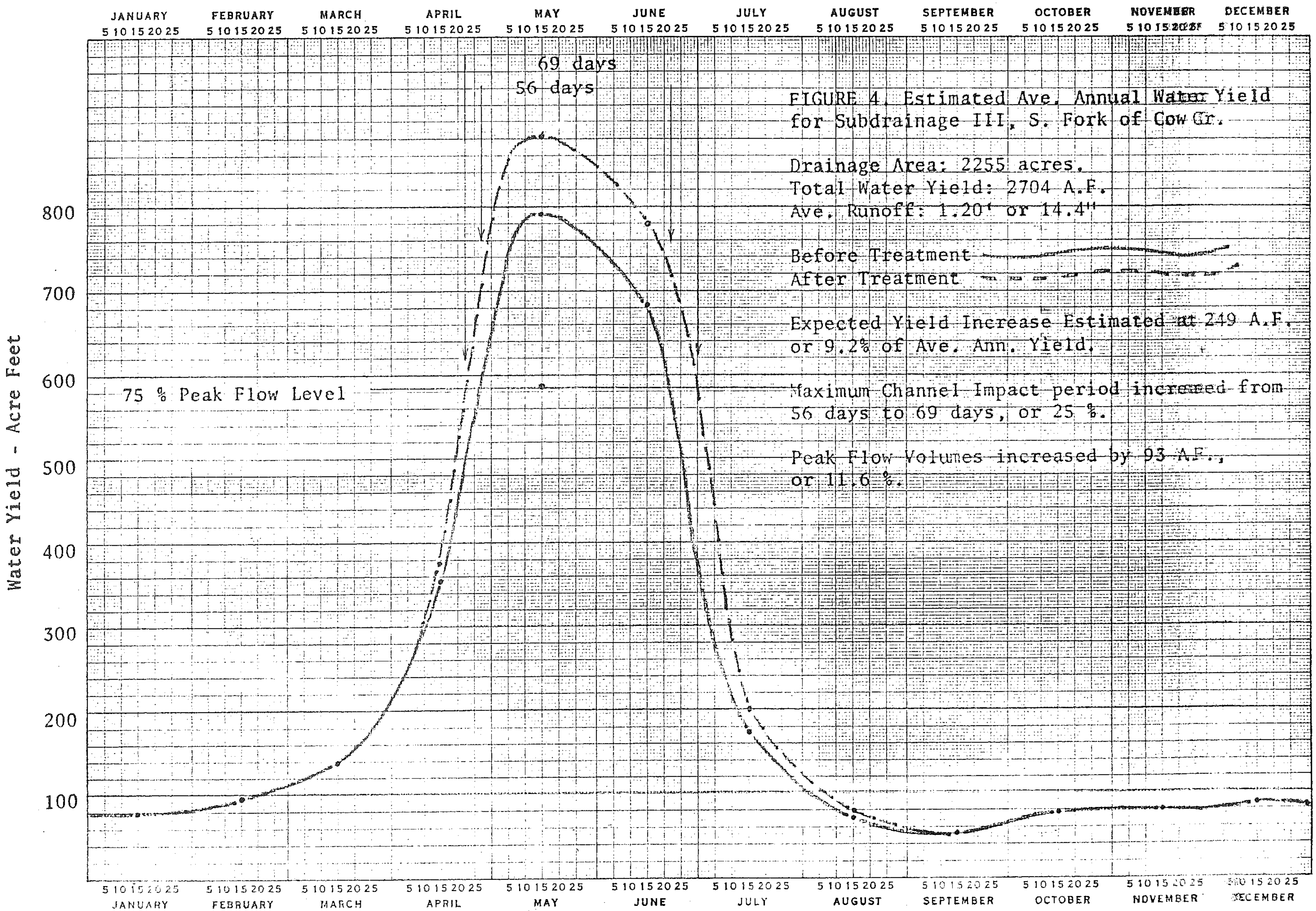


FIGURE 4. Estimated Ave. Annual Water Yield for Subdrainage III, S. Fork of Cow Cr.
Drainage Area: 2255 acres.
Total Water Yield: 2704 A.F.
Ave. Runoff: 1.20' or 14.4"
Before Treatment
After Treatment
Expected Yield Increase Estimated at 249 A.F. or 9.2% of Ave. Ann. Yield.
Maximum Channel Impact period increased from 56 days to 69 days, or 25 %.
Peak Flow Volumes increased by 93 A.F., or 11.6 %.
69 days
56 days
75 % Peak Flow Level
Water Yield - Acre Feet
100
200
300
400
500
600
700
800
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
5 10 15 20 25

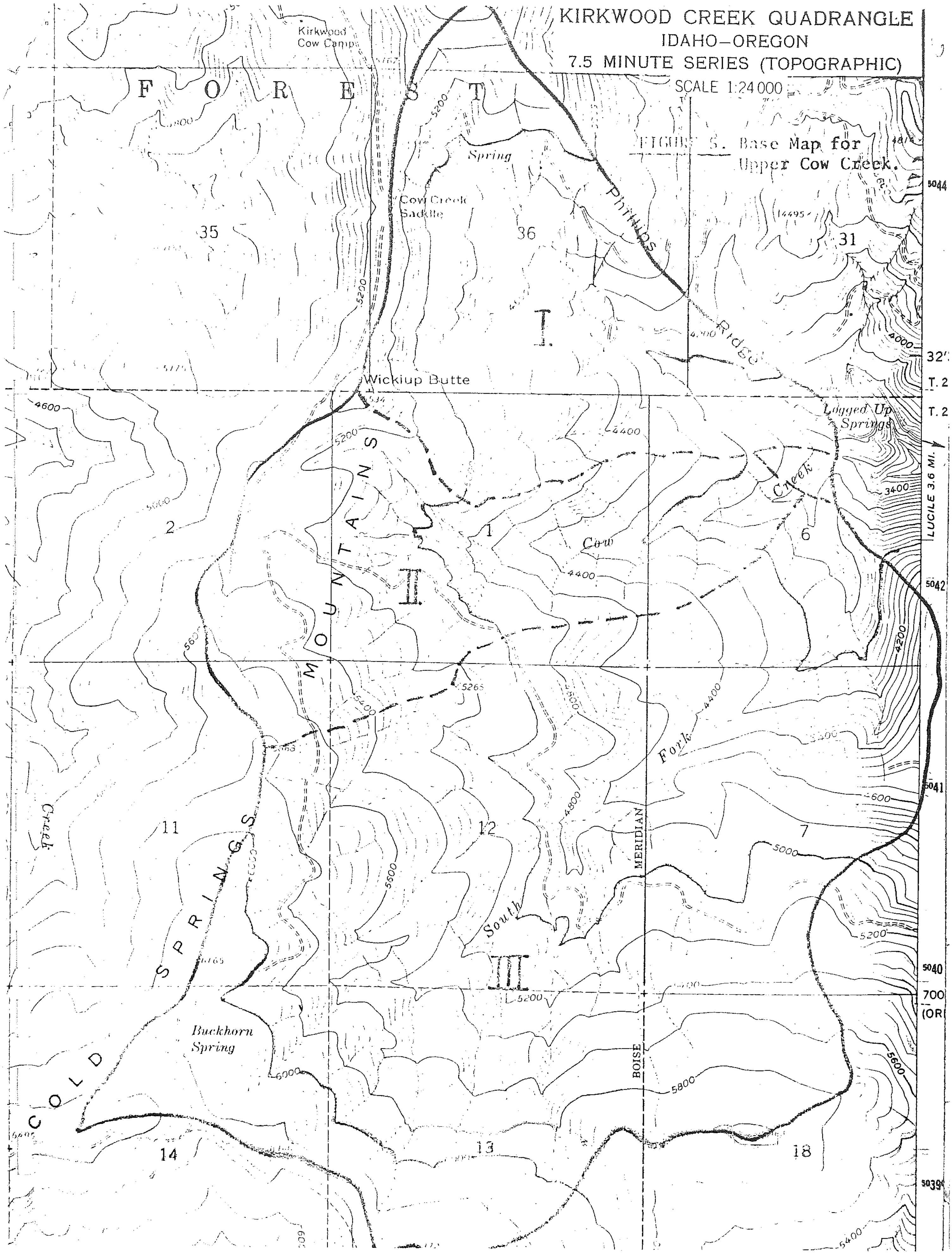


FIGURE 5. Base Map for Upper Cow Creek.

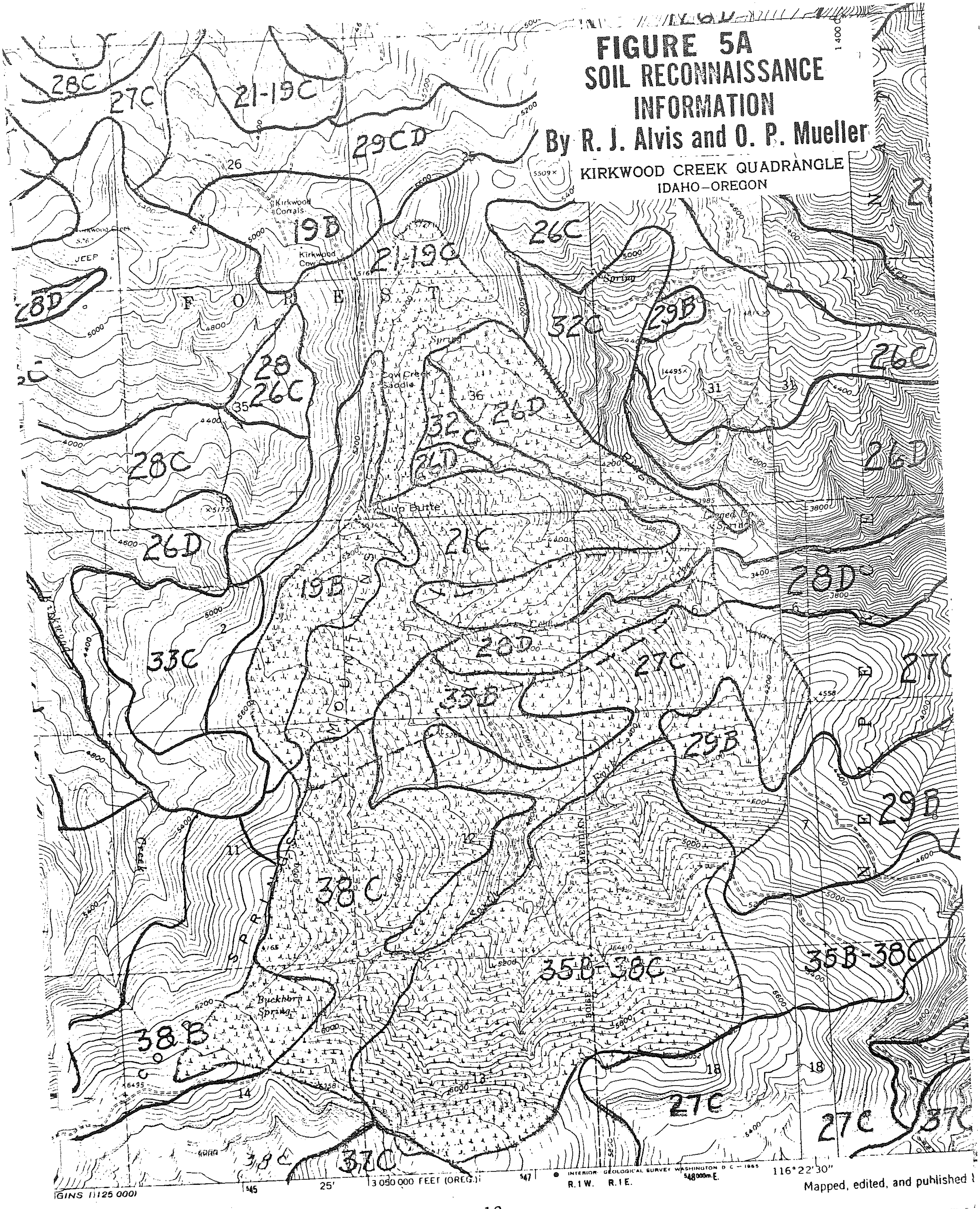
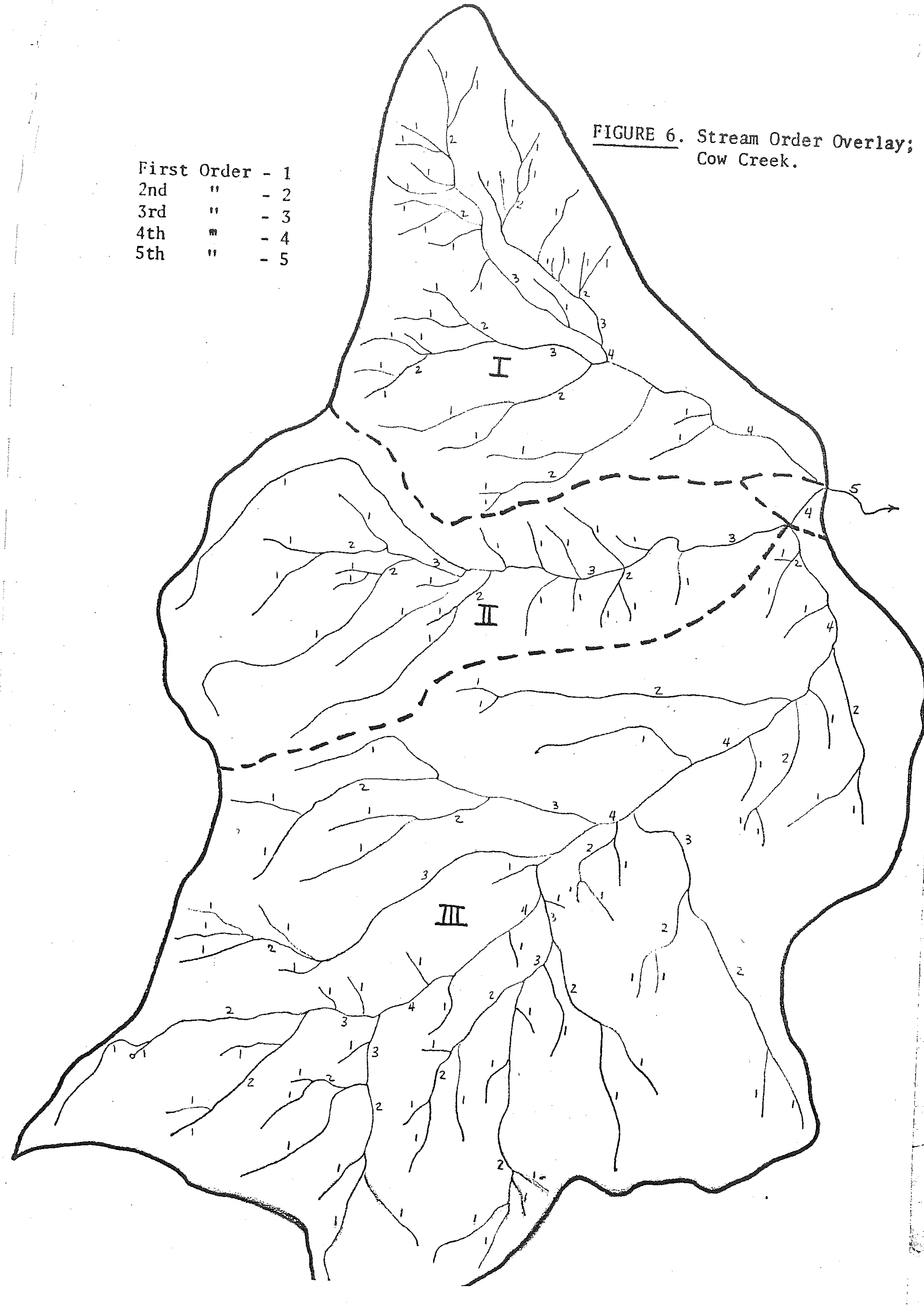


FIGURE 5A
SOIL RECONNAISSANCE INFORMATION
By R. J. Alvis and O. P. Mueller

FIGURE 6. Stream Order Overlay; Cow Creek.

First Order - 1
2nd " - 2
3rd " - 3
4th " - 4
5th " - 5



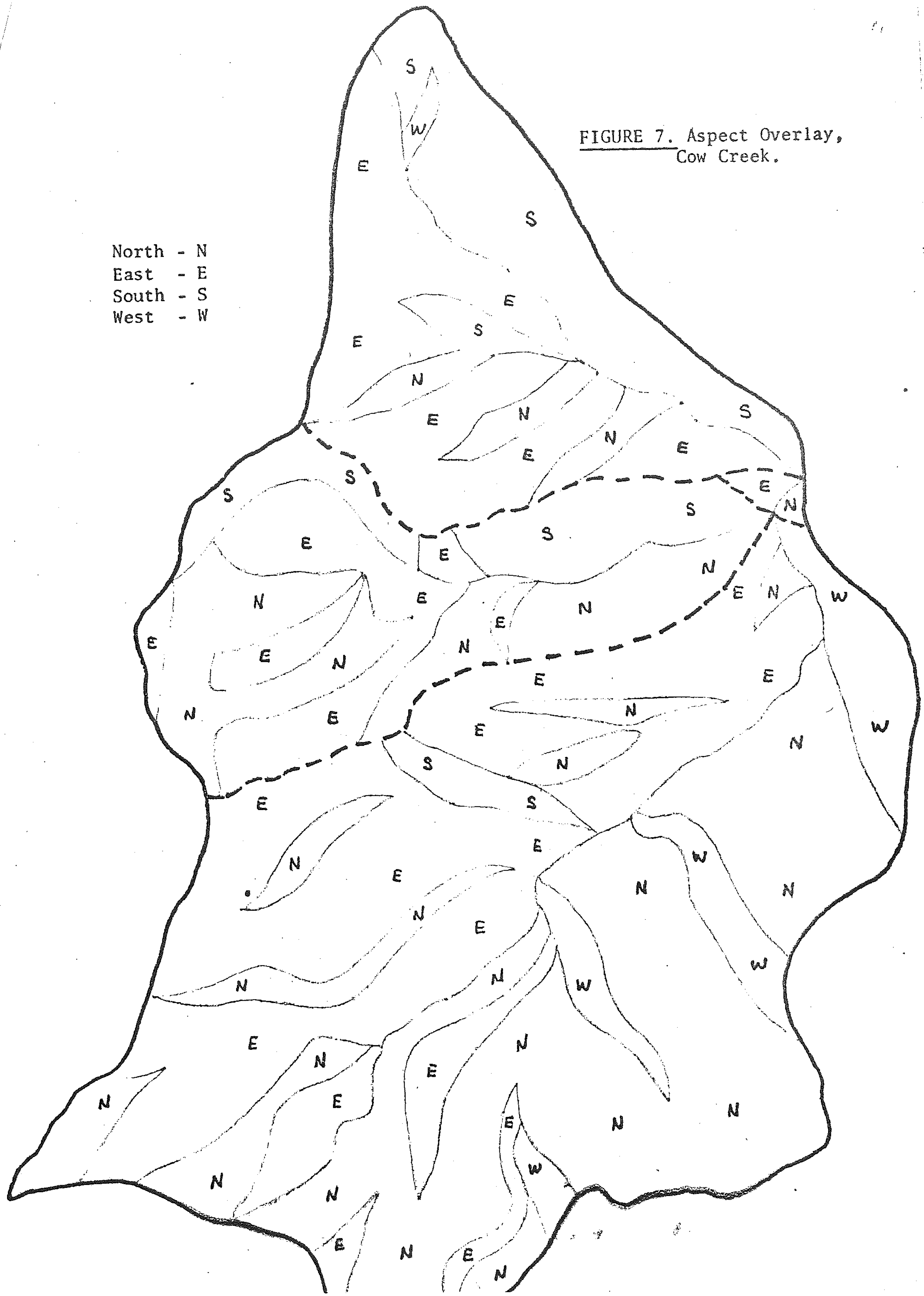


FIGURE 7. Aspect Overlay, Cow Creek.

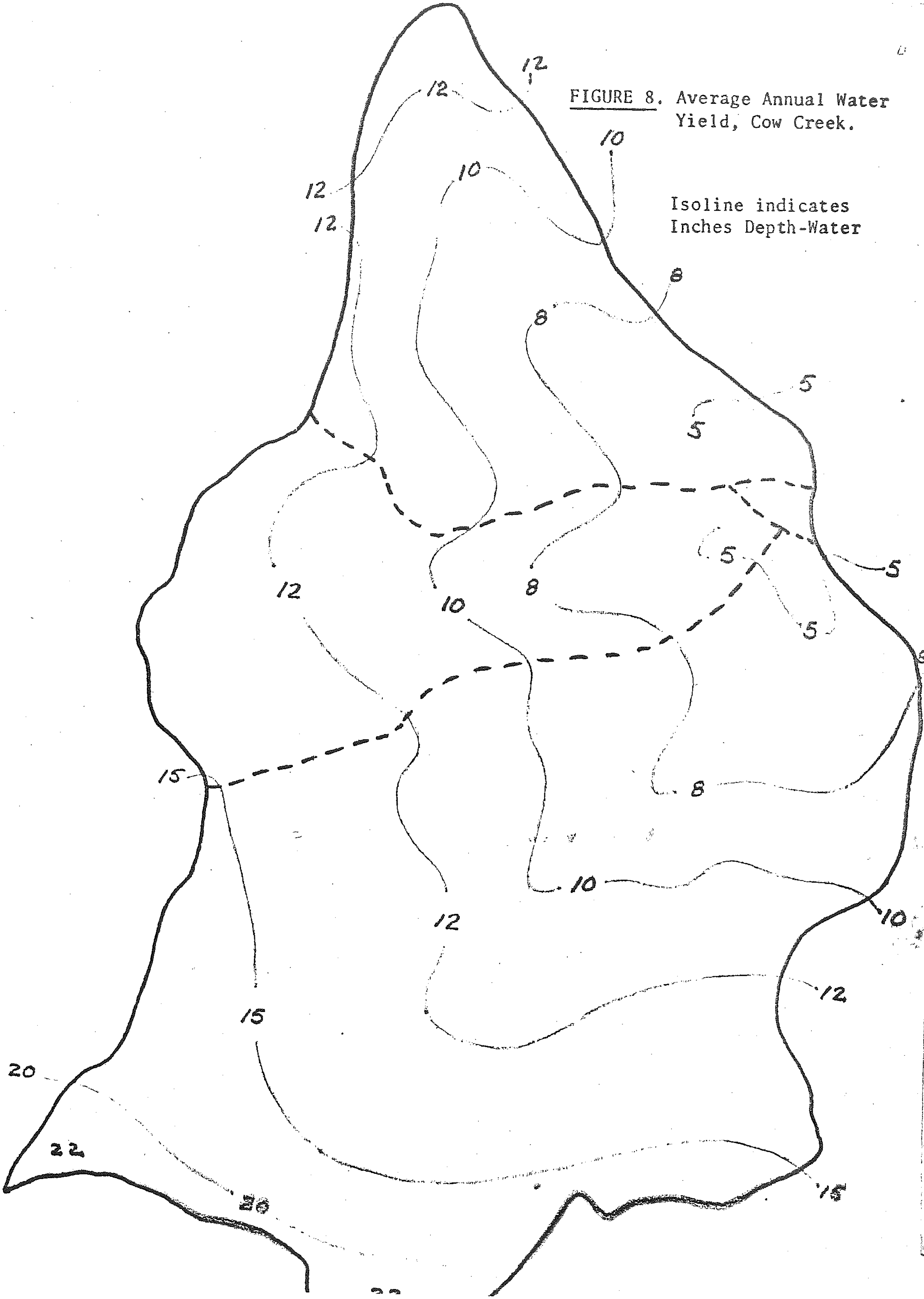


FIGURE 8. Average Annual Water Yield, Cow Creek.

Isoline indicates Inches Depth-Water

FIGURE 9. Sample Development Overlay, S. Fk. Cow Cr.

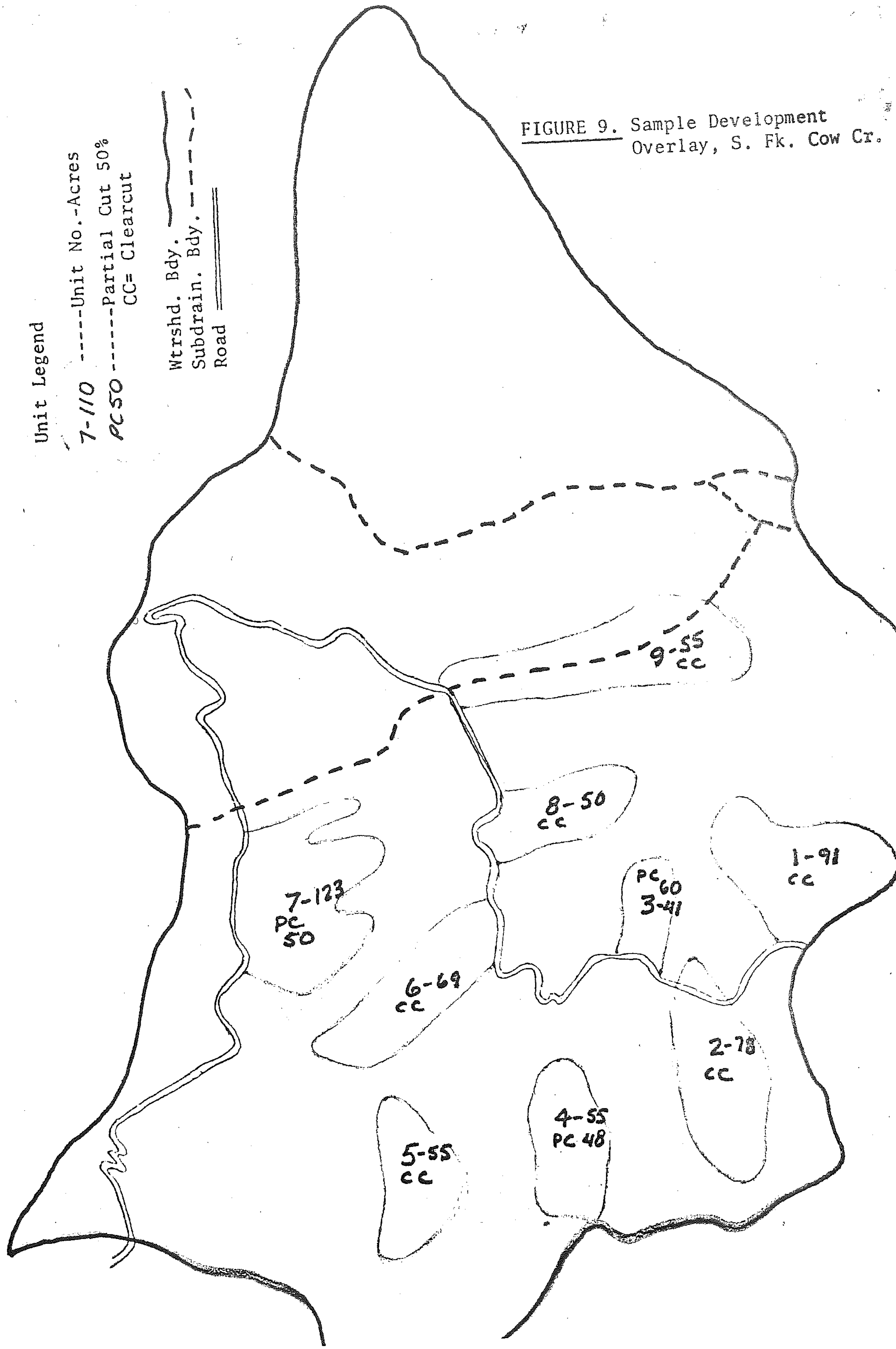


TABLE 1. Stream Channel Orders.

Subdrainage		1st	2nd	3rd	4th	5th	6th	Totals
	Mi.							
	No.							
	Mi.							
	No.							
	Mi.							
	No.							
	Mi.							
	No.							
	Mi.							
	No.							
	Mi.							
	No.							
	Mi.							
Totals	No.							
Ave. Chan. Lengths	Ave.							

TABLE 2. Drainage Area by General Aspect; North, South, East, and West.

Subdrain.		N	S	E	W	Total
	A					
	%					
	A					
	%					
	A					
	%					
	A					
	%					
	A					
	%					
	A					
	%					
	A					
Total	%					

TABLE 3. Drainage Area by Elevation Zones.

Subdrain.		2-3000	3-4000	4-5000	5-6000	6-7000	7000 +	Total
	A							
	%							
	A							
	%							
	A							
	%							
	A							
	%							
	A							
	%							
	A							
	%							
Total	A							
	%							

A = Area, Acres
% = Percent of subdrainage area.
AF = Acre Feet of Water

TABLE 4. Runoff or Water Yield by Inch-Depth Zones.

Subdrain.	In Ft									Total
	A									
	AF									
	A									
	AF									
	A									
	AF									
	A									
	AF									
	A									
	AF									
	A									
	AF									
Total	A									
	AF									

TABLE 5. Average Monthly and Yearly Water Yields for Selected Gaging Stations in the Nezperce National Forest (From USGS WSP 1737), Acre Feet. M = 1000's

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
I. S.Fk.Clwtr,R, near Gvlle Ave.Yield,A.F. % of Annual	18400 2.7	18800 2.8	30400 4.5	113100 17.0	217800 32.0	143500 21.2	44400 7.0	15000 2.2	11100 1.6	18400 2.7	20000 2.9	22800 3.4	675700
II. S.Fk.Clw.R. near Elk City Ave.Yield A.F. % of Annual	4785 2.6	4840 2.6	8675 4.6	39550 21.5	64380 35.0	30660 16.7	9170 5.0	3340 1.8	2610 1.4	4575 2.5	5250 2.9	6200 3.4	183880
III. Clwtr.River @ Kamiah Ave.Yield A.F. % of Annual	179M 2.8	199M 3.2	288M 4.5	869M 13.8	1963M 31.3	1539M 24.5	434M 6.9	122M 1.9	90M 1.4	166M 2.6	202M 3.3	229M 3.6	6280M
IV. Selway R. near Lowell Ave. Yield A.F. % of Annual	74000 2.6	80800 2.8	113400 3.9	374000 13.1	832500 29.4	784500 27.5	215600 7.9	58300 2.1	40900 1.5	78000 2.7	89600 3.1	97300 3.4	2843 M
V. Salmon R. @ White Bird Ave.Yield A.F. % of Annual	264M 3.0	253M 2.9	326M 3.7	758M 8.5	2314M 26.1	2515M 28.3	890M 10.0	355M 4.0	266M 3.0	322M 3.6	312M 3.5	300M 3.4	8876M
VI. N.Fork of Skookumchuck Ave. Yield A.F. % of Annual	350 2.9	497 4.2	767 6.5	2153 17.9	3944 32.8	2723 22.6	390 3.2	137 1.1	133 1.1	249 2.2	275 2.3	386 3.2	12028
VII. Main Fk.Horse Cr;,onMdw.Cr. Ave.Yield, A.F. % of Annual	335 6.0	228 4.1	361 6.4	677 12.2	1524 27.2	875 15.6	357 6.4	204 3.6	167 3.0	234 4.2	274 4.9	357 6.4	5597
VIII. Mdw.Cr. near Selway Falls. Ave. Yield A.F. % of Annual	11060 [illegible]	11114 [illegible]	12972 [illegible]	30941 [illegible].7	94195 29.6	94545 29.7	21647 6.8	81[illegible] [illegible]	8[illegible] [illegible]	[illegible]	[illegible]5	[illegible]378	[illegible]18623

TABLE 6. Monthly Water Yields for Drainage Area and Subdrainages.

Water Year	O	N	D	J	F	M	A	M	J	J	A	S	Annual
Monthly % of Annual Yld.													
Drainage Area Yield													
Subdrain.													

Percentage data developed from streamflow records at ______________________

TABLE 6. Monthly Water Yields for Drainage Area and Subdrainages.

Water Year	O	N	D	J	F	M	A	M	J	J	A	S	Annual
Monthly % of Annual Yld.													
Drainage Area Yield													
Subdrain.													

Percentage data developed from streamflow records at ____________________

TABLE 7. Monthly Distribution of the Water Yield Increase ("B" Value); Expressed as a Percentage of the Total Yield Increase Volume, by Elev. Zones and General Aspect.

	South						North					
Elev. Zone	Mar.	Apr.	May	June	July	Aug.	Mar.	Apr.	May	June	July	Aug.
2-3500	30	40	25	5	0	0	10	30	40	20	0	0
3500-4500	20	30	40	10	0	0	5	20	40	30	5	0
4500-6000	10	20	45	20	5	0	0	5	35	45	10	5
6000-7000	0	10	50	25	10	5	0	5	25	50	15	5
Elev. Zone	West						East					
2-3500	25	35	35	5	0	0	10	35	45	10	0	0
3500-4500	15	25	40	15	5	0	5	25	40	25	5	0
4500-6000	5	15	45	25	5	5	0	10	40	35	10	5
6000-7000	0	5	45	40	5	5	0	5	35	45	10	5

PART II

Estimating the Effects of Planned or Existing Timber Cutting on Annual and Monthly Water Yields.

1. Nezperce Formulas for Determining Timber Cutting Limits in 3rd, 4th, and 5th Order Drainage Areas:

Based on a local analysis of runoff patterns-volumes, terrain-landform, and channel condition-soil areas; it is assumred that most 3rd through 5th order drainage channels on the Nezperce can sustain a 10% increase in average annual runoff as a result of timber harvesting or vegetative manipulation.

The following Nezperce Formula I was developed to express a rapid means of determining a key guideline value known as ECA. The ECA value is the total area in acres within a drainage that can or will be in an "Equivalent Clearcut" condition; consisting of clearcuts, partial cuts, roads outside of clearcuts, burns, recent slides, etc. Through application of this formula, it is possible to estimate prior to drainage development, how much of the land area in a drainage can be in an equivalent clearcut condition and not cause an increase in average annual yield values above that which the drainage channel can safely transmit during years when the annual flow volume is average or above.

Formula I.

$$ECA = \frac{A(I)}{F(R)} \qquad \text{where:}$$

A = Average Annual Water Yield in Acre Feet
I = Prescribed Increase Limit for Ave. Annual Water Yield in %.
F = On-site Water Yield, Increase Factor in %.
R = Average Runoff for Treated Area in Feet.
A(I) = "B" = Allowable or Calculated Water Yield Volume in Acre Feet.
DA = Drainage area in acres.
ECA ÷ AA = % of Drainage Treated.
B ÷ F = Y = Pre-treatment Water Yield of Treated Area, Acre-ft.
A ÷ DA = R in Feet.

The increase in average annual water yield that has resulted from previous development in a drainage may be estimated with use of the Nezperce Formula II. In order to calculate the existing ECA for such a drainage, graphs provided as Figures 10 and 11 allow an estimate of the ECA value for partial cuts and clearcuts older than one year.

<u>Formula II</u>

$$I = \frac{(ECA \times R)\ F}{A}$$ where:

I = Percent Increase in Average Annual Water Yield Due to Vegetative Manipulation.
ECA = Existing Equivalent Clearcut Area in Acres.
R = Ave. Runoff of Treated Area in Feet.
F = On-site Water Yield Increase Factor in %.
A = Average Annual Water Yield of Subdrainage in Acre Feet.

$$\left.\begin{array}{l} ECA \times R = Y \\ \frac{B}{F} = Y \end{array}\right\} = \text{Pre-treatment Water Yield of Treated Area in Acre Feet.}$$

(Y)F = B = Water Yield Increase Volume in Acre Feet.

$(R)F = B_1$ = Water Yield Increase, Feet-Depth.

2. Discussion of Formula Components:

DA = DRAINAGE AREA - Simply the planimetered area, expressed in acres, of the subdrainage being considered for analysis. Generally subdrainages within a large drainage or drainage area (i.e.: PWI Watershed) are delineated on the basis of stream orders. That is, drainage areas of 3rd, 4th, and in some cases 5th order size provide a means of characterizing and dividing a larger drainage in terms of "logical watershed units." Stream orders at this level of analysis are usually based on the degree of channel branching found on the standard USGS topographic map with a distance scale of 2.65"/mile. Figure 1 defines stream orders and describes the method used for delineation.

A = AVERAGE ANNUAL WATER YIELD of the subdrainage. This value is obtained by planimetering the area between runoff isolines for the local area. Isolines for the Nezperce N.F. are obtained from the atlas of "Water Yield Maps for Idaho," published by the Agri. Research Service, 1968. For the area between any two isolines, the average runoff value used for volume calculations is the average of the upper and lower isolines. For example, all of the area within a subdrainage that is between a 10-inch line and a 14-inch line is considered to yield an average of 12 inches of runoff per acre per year.

I = INCREASE LIMIT FOR Average Annual Runoff in %. This value is a guideline used to equate the magnitude of the impact upon a drainage system that develops from removal of timber vegetation. For the Nezperce Forest area, an average of 10% increase in average annual yield for 3rd, 4th, and 5th order drainages is used as a limiting factor. The term average indicates that this value can vary with location, and primarily due to soil type; that is the increase limit may be 5 or even 10 percent higher in stable soil areas with a good to excellent stream channel condition rating. Conversely, the limit could be decreased in certain high hazard soil areas with unstable or poor stream channel conditions. The percentage limit is based on the following assumption: when the estimated or calculated average annual flow is exceeded by more than 10%, stream channel damage will begin to occur. This assumption was derived from several on-site analyses conducted in the Region where the water yield increase from an active timber sale was related to accelerated stream channel damage. In addition, the assumption is based on an analysis of local USGS gaging station records where the total annual flow for each year during the period of record is compared with average annual flow in terms of departures upward or downward from the mean.

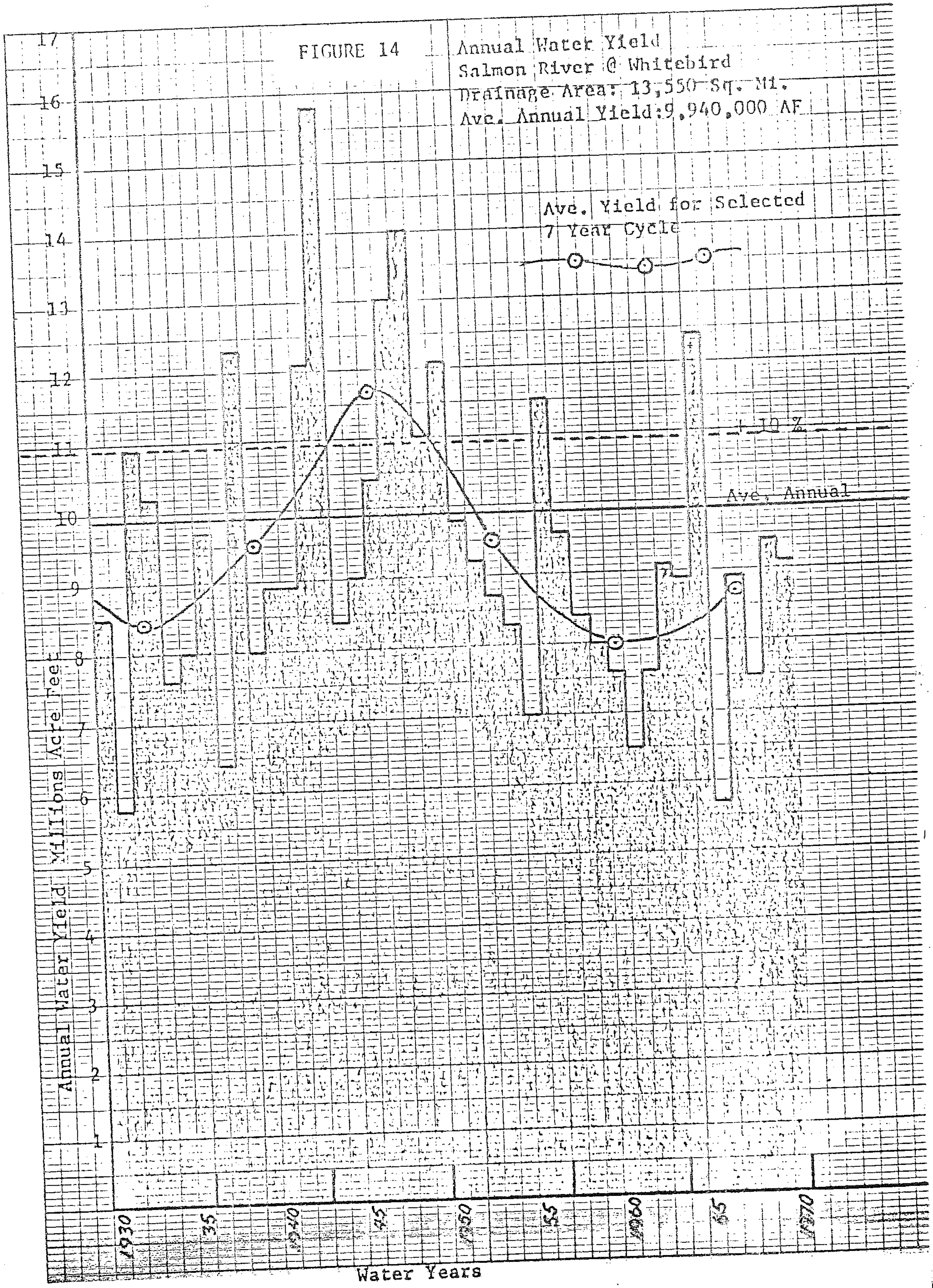


FIGURE 14
Annual Water Yield
Salmon River @ Whitebird
Drainage Area: 13,550 Sq. Mi.
Ave. Annual Yield: 9,940,000 AF
Ave. Yield for Selected
7 Year Cycle
+10 %
Ave. Annual
Annual Water Yield Millions Acre Feet
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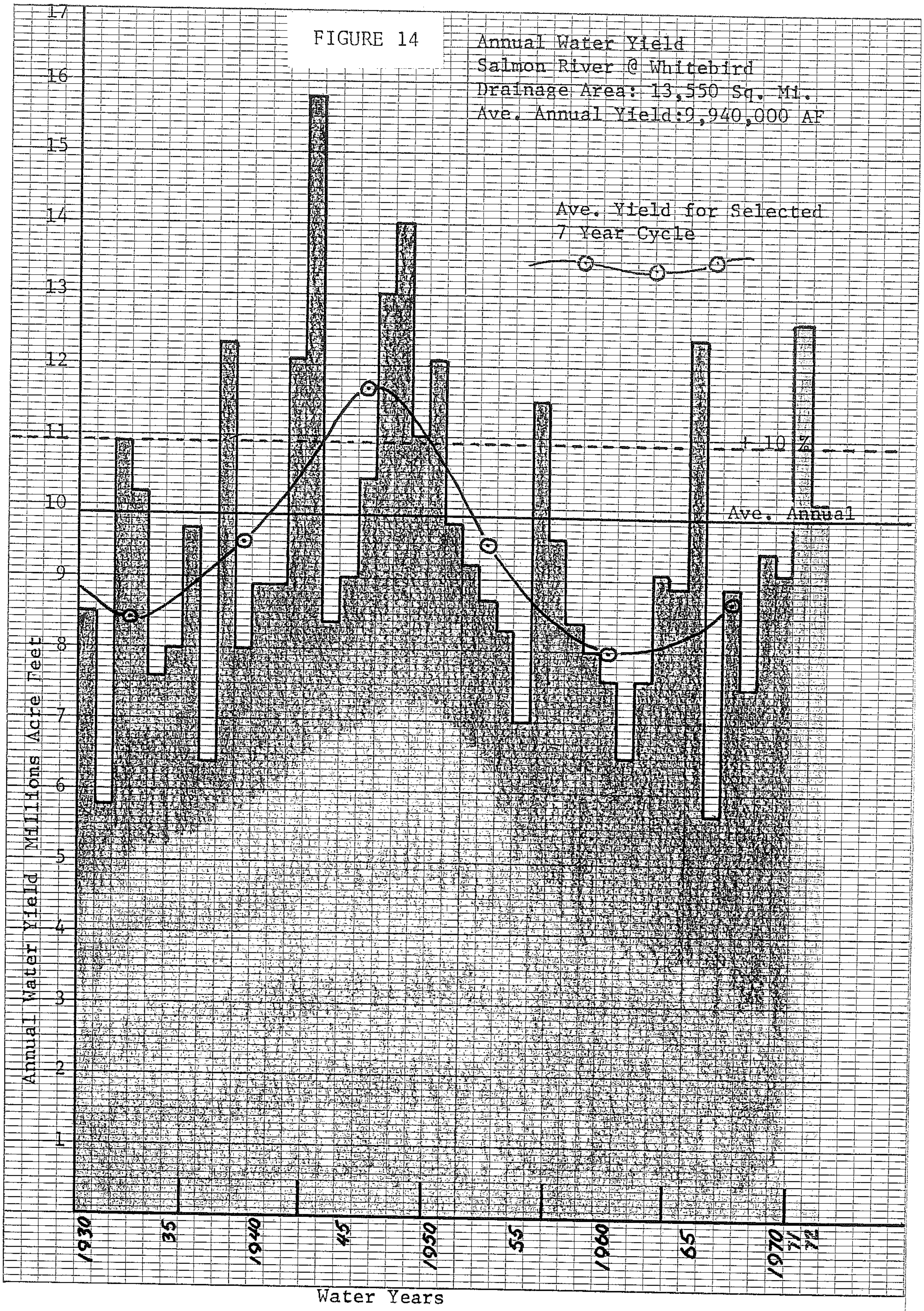
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Water Years

Figure 14 is a bar-graph depicting annual flow for the Salmon River at White Bird from 1911 through 1970. An analysis of the graph would indicate that for the period of record, the average annual or mean flow value was exceeded 24 years out of 57, or 42% of the time, with a range in plus departures upward from the mean of 2 to 40%. The average of plus departures is 25% above the mean, with an occurrence rate or frequency of once every 2.4 years. The annual flow exceeded the mean value plus 10% nineteen times, or about 33% of the time during the period of record. Annual flow exceeded the average plus departure of 25% some 12 times for the period of record, about once every five years of 21% of the time. Thus, if we assume that annual flows ranging from 10% to 25% above the mean value are moderately high to high flows; and that these flow volumes cause significant movement of stream bank and/or bottom materials during the spring runoff season: then a significant yield increase due to vegetative manipulation on top of any one of the 10% plus years would tend to cause development of stream channel damage in the form of aggradation, degradation, and bank cutting. Conversely, annual flows are equal to or less than "10% above the mean" about 70% of the time, which would indicate a 10% increase in stream flow could be transmitted through the system most years without developing an acceleration in movement of stream channel materials. It is felt that a 10% allowable increase in the average annual stream flow is a relatively safe tolerance in the above situation.

B = ALLOWABLE OR CALCULATED WATER YIELD INCREASE VOLUME IN ACRE FT. - This value is simply a product of the drainage average annual water yield times the percentage increase limit, expressed in acre feet of water as used in Formula I; or in Formula II a product of the average pre-treatment yield of a treated area times the water yield increase factor, expressed in acre feet.

F = ON-SITE WATER YIELD INCREASE FACTOR IN % - The water yield increase factor is an expression of the increase in the normal or average water yield of any particular land unit that occurs as a result of the removal of vegetation, i.e., timber harvesting. The increase develops from three primary hydrologic sources. The largest part of the increase develops from the significant reduction in loss of moisture from the soil due to transpiration and evaporation, or "ET." This is to say that when the timber is removed from a site, the soil moisture levels on that site are not depleted through transpiration to the extent that would occur with timber in situ. Thus with the soil moisture reservoir not requiring as much water for re-charge from precipitation in order for runoff to be in effect, there is a resulting surplus of precipitation that will normally show up as an increase in runoff.

A second source of water yield increase develops from a redistribution of snow into openings in the forest canopy such as clearcuts. The term "redistribution" refers to the phenomena that occurs when snow carried by the ambient air mass across the top of the canopy is deposited into a clearcut area due to a disruption of the shear plane at the canopy level. In effect, the standing timber around the edge of a clearcut acts as a snowfence, causing more snow than normally would fall in the timber area to settle into the relatively still air in the clearcut unit.

The third source of the water yield increase is a result of the reduction of interception losses that occur with snow or rain deposited on the forest canopy. Elimination of the forest canopy as in a clearcut would provide a significant reduction in above-ground-level evaporative losses, hence causing more moisture deposited at the surface for transfer to soil storage or runoff.

Recent indications from research in north Idaho suggest that for the general area in which timber is harvested on the Nezperce, i.e., 4-6000' elevation zone, the maximum increase to water yield from a reduction of transpiration loss can be as high as 6 inches of water; with a range of 3 to 6 inches possible increase depending on soil depths, etc. The redistribution of snow across a watershed and the subsequent increase to water yield may vary from 2 inches to a high of 4 inches of additional water. An increase to water yield due to a reduction of the interception factor can result in additional water in the amount of 1 to 3 inches. Thus, the total amount of water that could be available as additional runoff would range from 6 to 13 inches. Within the Nezperce area, for example, there could be a potential for a water yield increase factor ranging from 30 to 70 percent. For purposes of estimating the water yield increases due to timber cutting, it is assumed the water yield increase factor may vary from about 35% at 4000 feet elevation to 45% at 6000 feet. These values seem reasonable when compared with water balance calculations, wherein precipitation for the 4 to 6000' zone is estimated at 38 inches annually; and the annual runoff is calculated at 20 inches, with an estimated water loss to evapotranspiration of 18 inches.

Considering local soil types, precipitation patterns, climate and timber types, it is estimated that on the average there would be about 7 or 8 inches water diverted from the evapotranspiration loss of 18 inches to runoff. This would in effect be the average water yield increase factor of about 40% that would be applied to equivalent clearcut area through Formulas I and II in this elevation zone.

Y = AVE. PRE-TREATMENT YIELD OF TREATED AREA IN ACRE FT.

R = AVE. RUNOFF OF TREATED AREA IN FT. - The "Y" value is the average annual water yield of the timber harvest units (clearcut or partial cut) determined by multiplying their area in acres by the average annual runoff value, in feet, for the treated area. The "R" value for the treated area is simply the most representative or closest water yield isoline value converted from inches to feet. For a precise estimate of pre-treatment yield, the isoline value in or adjacent to the unit would be used, with each unit figured separately and their yields totaled for the subdrainage. A close approximation for a rapid estimate may be obtained by totaling the area of the cutting units and multiplying by the average runoff (ft.) of the subdrainage in which the units are located.

ECA = EQUIVALENT CLEARCUT AREA - This term describes the total area within a particular subdrainage that does or will exist in a clearcut condition. An ECA value is determined by adding the area actually in a clearcut condition with an "equivalent" clearcut area for roads outside of clearcut units, and partial or selective cut units. The graph shown as Figure 10 provides a means of estimating what percent of a particular partial cut unit to consider as being in an equivalent clearcut condition.

3. Procedures

a. Calculate the ECA and Formula I values for each subdrainage, presenting data in tabular form as shown in sample Table 8:

Table 8 - ECA and Formula I Date by Subdrainage

Subdrainage No.	DA	A	I	B	F	Y	R	Allowable ECA Ac	Allowable ECA %	
III	2255	2704	10	270	40	675	1.20	562	25	

b. In those subdrainages with existing development, use Formula II to determine existing ECA. In order to depict graphically the effects of an increased water yield on a subdrainage hydrograph from existing or planned development, it is necessary to plot the value for "B" (allowable or calculated water yield increase volume) by months over the average annual hydrograph.

From Table 7 select the elevation zone and aspect that most nearly represents the subdrainage in question. The data within the table are percentage values for the months of the snowpack melt-season, that when applied to the water yield increase volume ("B") provide a volume estimate of how much of the total yield increase volume will appear as runoff during a particular month. Plot these monthly increase volumes over the hydrograph of average annual yield, and draw in a new curve to depict the effects of a yield increase.

c. Determine the "maximum channel impact" period and the increase in peak month volumes for the subdrainage.

Maximum channel impact period is assumed to be that period of time from when the annual hydrograph rises above a line drawn at 75% of the peak flow volume (or highest average monthly yield) to when it again drops below the 75% level. Note Figure 4. As an example, the S. Fk. of Cow Creek yields a peak flow in May of some 795 A.F. A line would then be drawn across the hydrograph at 586 A.F. or 75% level. The maximum channel impact period then becomes the number of days between the point where the rising hydrograph crosses the 75% line and where it again falls below the line. After the water yield increase volumes are calculated and plotted over the hydrograph, and a new curve drawn, the increase (in terms of days) in the channel impact period may be determined and expressed as a percentage increase.

Using the new hydrograph curve, determine the increase in peak flow for the "high" month of May, and express as a percentage increase over the average peak-flow-month yield.

4. Reduction of Water Yield Increase Following Vegetative Recovery: The combination of three graphs shown in Figure 15 represents the three principal hydrologic sources of a water yield increase that will usually develop following a timber harvest in the north Idaho area. The "recovery" curves indicate the probable rate at which a yield increase will be reduced, assuming that vegetative recovery within a harvest unit is proceeding normally.

The upper graph represents the maximum evapotranspiration increase that will develop for water yield, and the rate at which this increase is reduced through recovery of on-site vegetation. It is noted that for the first year after cutting, the maximum amount of water that can be made available to streamflow is approximately 6 inches. This value is reduced each year, assuming there is a normal "return" rate of vegetation, until it is near zero at 16 to 20 years after treatment. The assumption used here (based on research investigations) is that at about 20 years of age, the new stand of timber will have fully taken over the rooting zone of the original cutting unit and evapotranspiration rates will be at or near pre-treatment levels.

The middle graph represents the "redistribution" of snow into clearcut openings and the subsequent increase to water yield. Research findings suggest that this input to the water yield increase factor persists to a significant degree until the crown level of the treated unit (i.e., a clearcut) regains 75 to 80 percent of its original height. As can be noted on the graph, the "redistribution" increase does not begin to fall off until about 30 years after treatment; and finally returns to 0 at about 100 years.

The third or lower graph represents the increase to water yield from a reduction of vegetative interception losses; and the rate at which this input to water yield is reduced as crown density is increased and crown closure is developed. Again, research evidence suggests that the interception portion of the water yield increase will be reduced to near normal pre-treatment levels at about 30 years, with some slight effects persisting until 100 years after treatment. The "interception" recovery rate is also based on the assumption that there is an average or normal regrowth of vegetation on the treated unit.

The following table is used to summarize the reduction of water yield increase components by years, and the percentage recovery values obtained are used to construct the recovery curve for ECA shown in Figure 16.

Table 9 - Reduction of Water Yield Increase Components by Years
Data in Inches of Water

Years	2	5	10	15	20	30	40	50	60	70	80	90	100
Evapotrans.	1.4	3.2	4.6	5.4	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.00
Redistr.	-	-	-	-	-	.2	.6	1.1	1.6	2.2	2.8	3.4	4.0
Intercept.	.5	1.1	1.5	1.8	2.0	2.2	2.4	2.5	2.6	2.7	2.8	2.9	3.0
Total	1.9	9.3	6.1	7.2	8.0	8.4	9.0	9.6	10.2	10.9	11.6	12.3	13.0
% of Recov.	14.6	33.1	46.9	55.4	61.5	64.6	69.2	73.8	78.5	83.8	89.2	94.6	100.0

I.E., % Recovery at 15 yrs. = 7.2 ÷ 13.0 = 55.4%

From Fig. 15, determine the reduction of produced water yield (in inches) by years for each of the three components: Evapotrans., Redistr., and Intercept. Total these values by year and divide by the total yield increase possible (13") which will provide an estimate of the percentage recovery of the treated area or ECA for a particular year or period of years.

The percentage recovery values are used as estimates of the recovery of the Equivalent Clearcut Area with time for any treated area, such as a timber sale, in a subdrainage. These values are graphed logorithmically in Figure 16. Using this graph, the degree to which ECA for any drainage has recovered can be determined. For example, using the data for Subdrainage III, Cow Creek, where the allowable ECA is estimated at 562 acres, and assuming this acreage was developed within the drainage as the initial timber sale; then working through the graph in Figure 16 and at the end of 5 years, the original ECA of 562 will have been reduced by 33% or to 376 acres. This process then provides a means of estimating how soon and to what degree a second timber harvest could take place within the subdrainage and not cause an increase in average annual water yield above the prescribed 10% limit.

5. Programming Timber Development for an Extended Period:

The purpose of the foregoing procedures and calculations is to finally bring the Forester to a position where he may program timber development for an extended time period using certain hydrologic restraints. The ability to estimate how much timber may be harvested within a particular subdrainage on a periodic basis, and still meet the requirements of selected or imposed constraints becomes essential to the long range planning efforts at the District level.

The following Table 10 provides an example of how, with the use of Formula II, timber development may be programmed within a drainage for any number of years. For purposes of this example, it is assumed that the total allowable ECA for Subdrainage III, Cow Creek, of 562 acres, exists as of 1972. The recovery by years of the existing ECA, as well as planned ECA for future years, is determined through Figure 16. The example as shown assumes that stream channel stability or soil area hazard ratings for this drainage are such that the normal yield increase limit of 10% would not be modified to some lower (or higher) value initially.

Table 10. ECA versus Water Yield Increase for Subdrainage III, Cow Creek, for the Period 1972-2000

Data: ECA Limit 562 acres DA = 2255 acres
I Limit @ 10%
R = 1.20' F = 40% A = 2704 Ac.Ft.

Year	1972	1973	1974	1975	1980	1985	1990	1995	2000
Existing ECA	562 I=9.9%	483 8.5%	438 7.7%	405 7.1%	309 5.4%	253 4.5%	219 3.8%	208 3.6%	197 3.5%
Planned ECA (Acres)				(200) 605 ECA I=10.7%	144 453	110	90	78	74
					(150) 603 ECA I=10.6%	108 471	82	69	58
						(100) 571 ECA I=10.1%	72 463	55	46
							(100) 563 ECA I=9.9%	72 482	55
								(100) 582 ECA I=10.3%	72 502
									(100) 602 ECA I=10.6%

As shown in Table 10, the existing ECA for the subdrainage of 562 acres in 1972 is reduced through vegetative recovery to 197 acres by the year 2000, with the I value (water yield increase) decreasing from 9.9% to 3.5%. In order to determine approximately when to re-enter the drainage with additional timber developments, simply determine the difference between the allowable ECA and the ECA estimated for some year in the future. In the case of this example, in 1975 the original ECA is reduced to 405 acres, with a difference of 157 acres.

An additional 200 acre development is shown for 1975, bringing the ECA up to 605 acres with an increase in water yield of 10.7%. The 200 acre development for 1975 is reduced to 74 acres by the year 2000. Additional developments are shown every 5 years through 2000, with subsequent recovery plotted for the remaining time period. ECA for any year in which further development is planned can be calculated by totaling the current existing ECA values of previous timber harvests, which if subtracted from the original allowable ECA determines the approximate amount of area that can be planned for harvest. For instance in 1995 the existing ECA is estimated at 482 acres, with a 100 acres planned for harvest.

Considering the 28 year time span shown in Table 10, planned timber harvest for Subdrainage III would total some 1312 acres of treated area or 58% of the drainage area placed under management. The 1312 acres scheduled for development would produce an estimated 15 to 19 million bd.ft. of timber, assuming a gross volume per acre of 12 to 15 M/acre for this section of the Nezperce. Thus, it becomes apparent that this type of development programming can be a useful tool for planning a systematic timber harvest over an extended period. Usefulness is implied in that the above method of analysis is a comparatively rapid means of logically estimating how much timber can be removed, at what rate it can be harvested, and how soon a selected intensity of management can or will be reached in any particular drainage, and still meet the requirements of prescribed hydrologic constraints.

A second approach to timber program planning is presented with Tables 11, 12, 13 and Figure 17. The tabularized data in these tables are based on the established recovery rates and show the reduction of a selected ECA value by year for a 100-year period, along with the accumulation of ECA by year if a sustained cutting rate is maintained. For instance in Table 11 (Sustained Cutting Rate of 100 Acres per Year) if 100 acres per year were placed in an equivalent clearcut condition for a 10-year period, then the total accumulated ECA would be 691 acres while the total area treated or placed under management would be 1000 acres. Tables 12 and 13 present similar data for sustained cutting rates of 300 and 500 acres per year. Figure 17 indicates how long these various cutting rates may be continued before the allowable ECA limit is reached in a particular drainage. This set of curves is based on the assumed average conditions for the Nezperce "harvest zone," where the water yield increase factor is set at 40% and the allowable increase in average annual water yield is 10%. Thus, if a watershed of 7000 acres was selected for treatment, the allowable ECA using the above F and I values is 1750 acres. A sustained cutting rate of 100 acres per year could be maintained for about 35 years, while 300 acres per year would reach the ECA limit in 8 years. It is apparent that the allowable ECA for a particular sized drainage as shown in Figure 17 will shift, depending on the F value used and if the prescribed water yield increase limit (I) is something other than 10%. As noted previously, the water yield increase factor may vary slightly depending on elevation; and the prescribed water yield increase limit will depend on the stream channel condition and soil-area erosion hazard ratings. Figure 18 provides a means of quickly determining what percentage of a drainage area may be in an equivalent clearcut condition for a selected F value and or range in I values from 1 to 20%. As an example, if a specific analysis of a timber sale area indicated that the water yield increase factor is 35%, and the channel condition survey-soil area hazard rating indicated that the normal 10% water yield increase limit should be reduced to 7%, then the allowable equivalent clearcut area for that drainage is shown as a percentage of the drainage area, i.e., 20%.

6. Adjustment of the Average Annual Water Yield Increase Limit for Stream Channel Condition and Soil Erosion Hazard:

The average annual water yield increase limit, or the I value in the Nezperce formulas, of 10% may be adjusted up or down, depending on stream channel condition and the potential soil erosion hazard for a particular drainage. The means by which a composite soil hazard rating is developed is illustrated in Tables 15, 16, and 17; with a water yield increase percentage adjustment range shown in Table 18. The initial step, as a portion of the basic resource inventory is to determine the area by soil type for each subdrainage as shown in Table 15, and developed from a soil area map which appears as Figure 5A.

The soil area interpretations for stability which appear in this case in the Soil Reconniassance Report for the Slate Creek and Salmon River Districts are used to develop a "composite soil erosion hazard" rating by soil type. Table 16 lists the soil-land types found in Cow Creek along with the six general stability-hazard sources. A relative numerical value is given to the verbal hazard ratings, shown in this case as: very low = 0, low = 2, moderate = 4, high = 6, and very high = 8. These values are inserted in the table, for each soil type, based on the Soil Report ratings given to each of the stability-hazard sources. The individual values for each soil type are totaled, which then provides a composite score or rating for the entire soil type.

The range in these total scores, in this case, may be from 0 to 48 with a breakdown shown in Table 16. As an example, soil type 27C has an erosion hazard rating for: mass failure of moderate (4), road cuts of very high (8), road beds of very high (8), skid trails of high (6); for a composite score of 38. Thus the soil type 27C as a unit has a high potential for soil erosion or stability hazard.

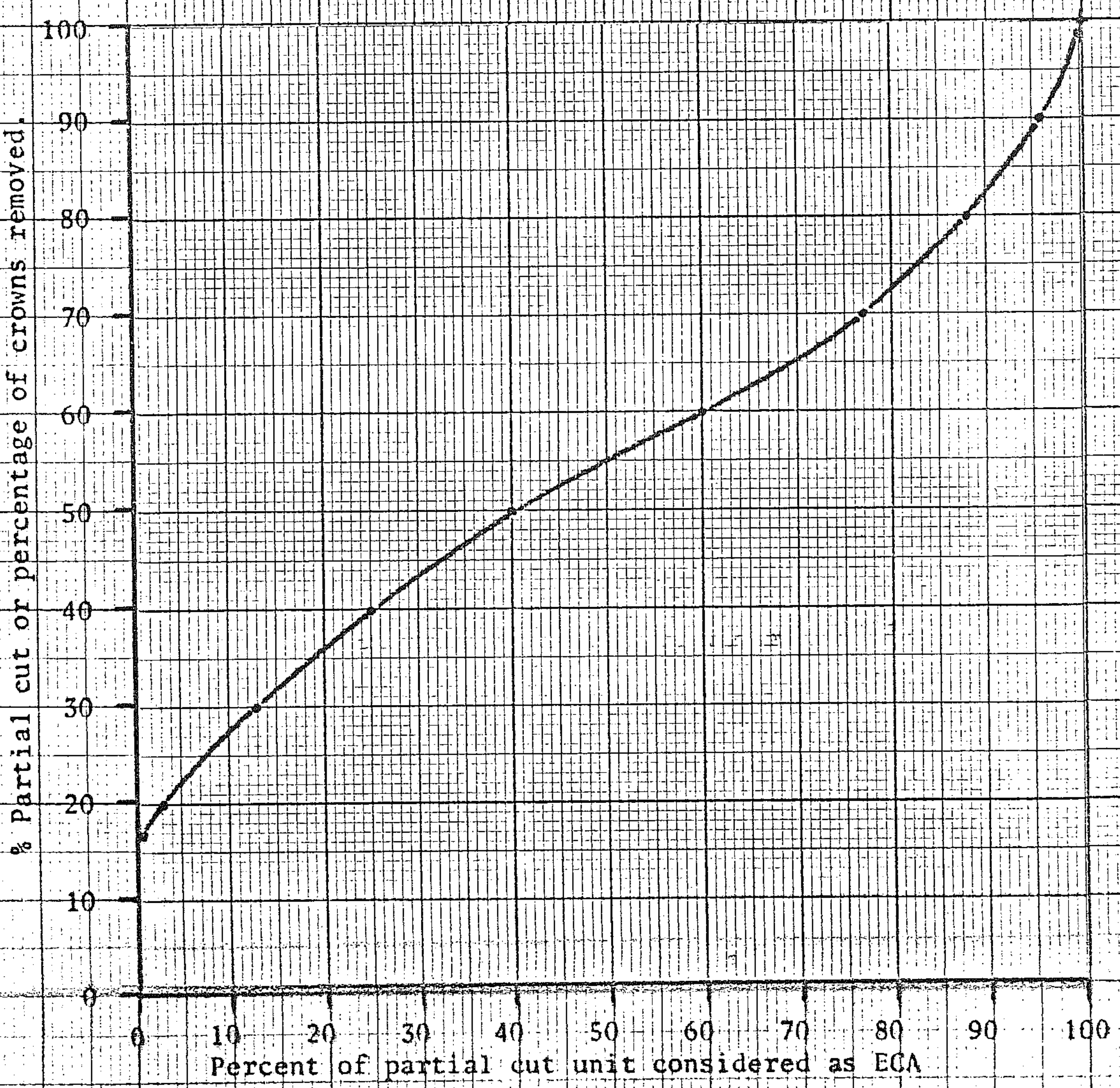
To finally adjust the water yield increase limit, it is necessary to consider all the soil types in a subdrainage to develop an average composite soil erosion-stability hazard rating. This is done for the Cow Creek subdrainage by weighting the soil type composite scores by the area of the soil type, totaling the weighted scores, and dividing the total weighted score by the total subdrainage area; as shown in Table 17. The amount by which the subdrainage average allowable water yield increase limit is adjusted for the drainage soil erosion potential is shown in Table 18.

The stream channel condition survey procedures used on the Nezperce result in a particular subdrainage channel being classified as to its ability to resist the impact of increased water yield. Table 19 lists the suggested water yield increase limit adjustments for the channel condition classes of 1 thru 8. Section VI of this handbook discusses the procedures of stream channel condition surveys, and how the average subdrainage channel ratings are obtained. Table 20 is an example for the subdrainages in Cow Creek wherein a "net allowable" water yield increase limit is determined from summarizing the channel condition and soil erosion hazard percentage adjustments. In the case of this example, Subdrainage III of Cow Creek is assumed to have a channel condition class of 5, for a yield increase adjustment of -1%. The average composite hazard rating of 22.9 which is a Moderate rating results in a yield increase adjustment of 0%. Thus, the net allowable water yield increase limit is set at 9% of the subdrainage average annual water yield.

There are situations on the Nezperce where stream channel condition survey data is not available; and due to certain manpower, fiscal, and time restraints, this information may not be available at the outset of development planning. In these cases, where Region 1 Stream Habitat Survey Data is available, it is possible to estimate the stream channel condition through a comparison process as illustrated in Table 21.

FIGURE 10. Estimating the Percent of a Partial Cut Unit to Consider as ECA. (4500 - 6000 Ft., Nezperce)

Example: An 80 acre partial cut unit with 50% of the crowns removed would have an ECA of 40% or 32 acres.



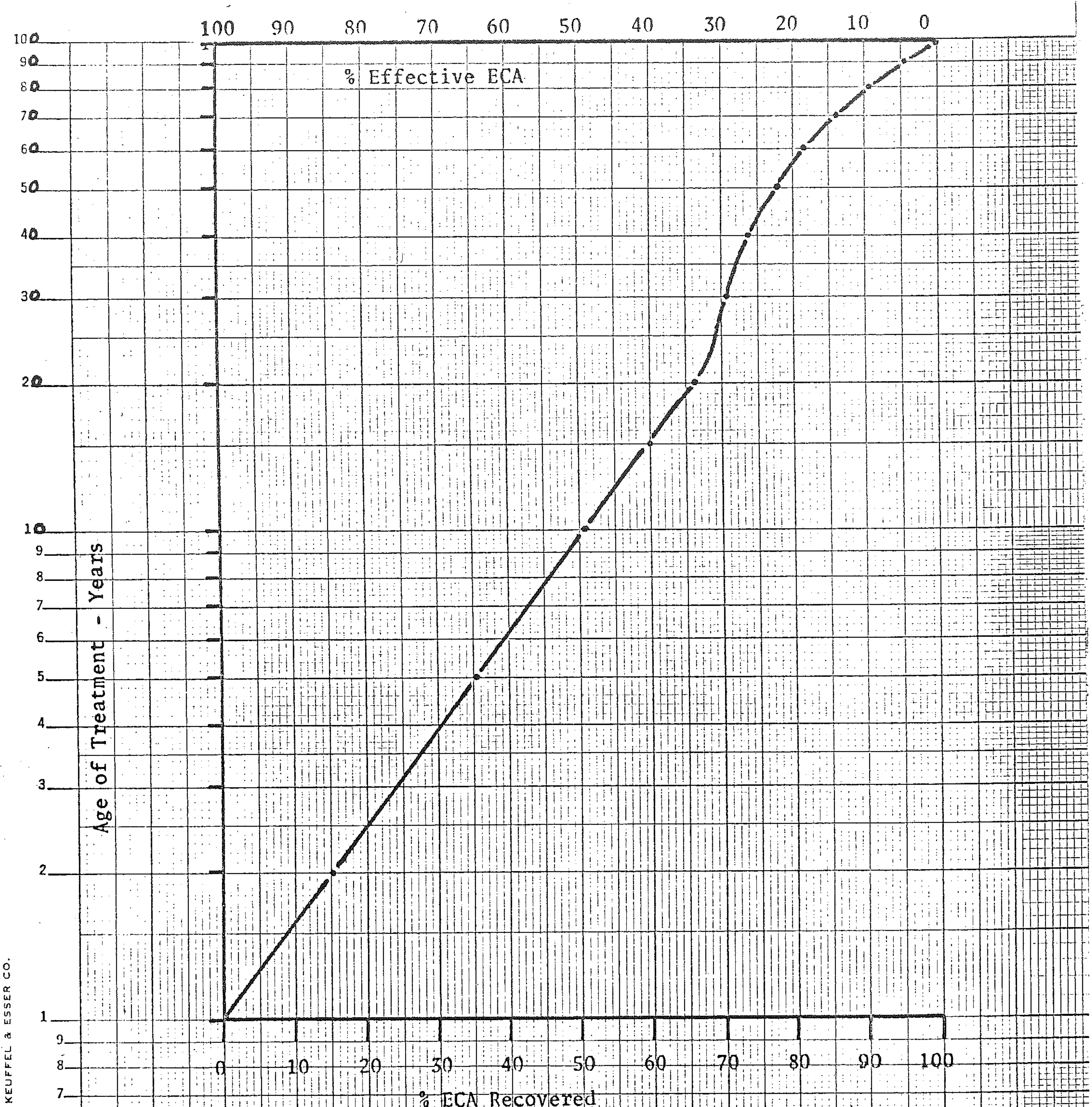


FIGURE 11. Percentage Recovery of Equivalent Clearcut Area by Years After Harvest.

Example: If a particular subdrainage had contained 500 acres ECA as a result of a timber sale that was now 5 yrs. old, the ECA would have been recovered by 36 %, or in effect reduced to 320 acres.

To determine the recovery of a partial cut unit and its subsequent ECA value, use Fig. 10 and 11 as follows: Assumption; 100 acres of partial cut @ 50% crown removal that is now 5 yrs. old. From Fig. 10 it is determined that the 100 acre unit had an original ECA value of 45 acres. From Fig. 11 it is determined that 45 acres ECA at 5 yrs. would be recovered by 36%, or the ECA would be reduced to 29 acres.

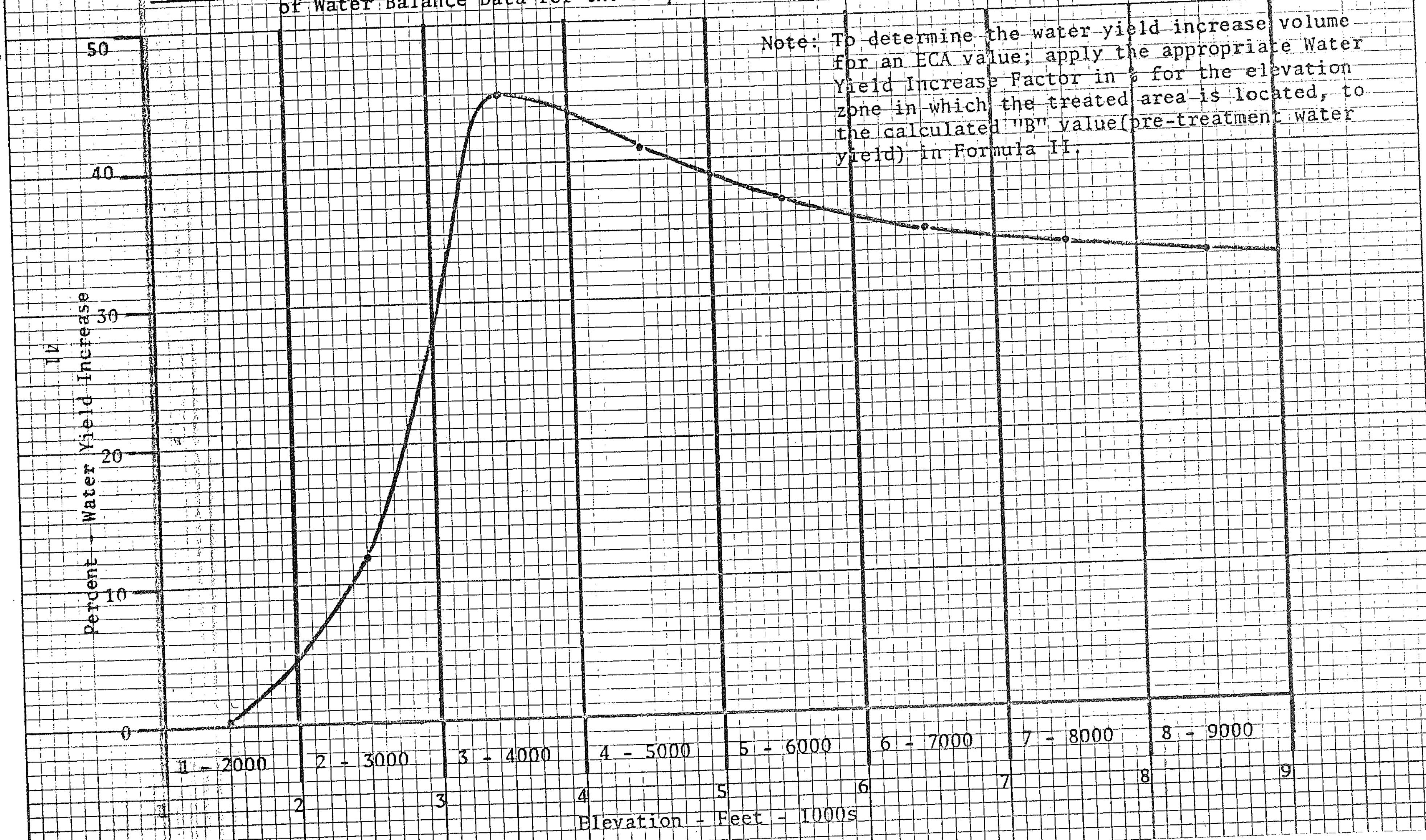
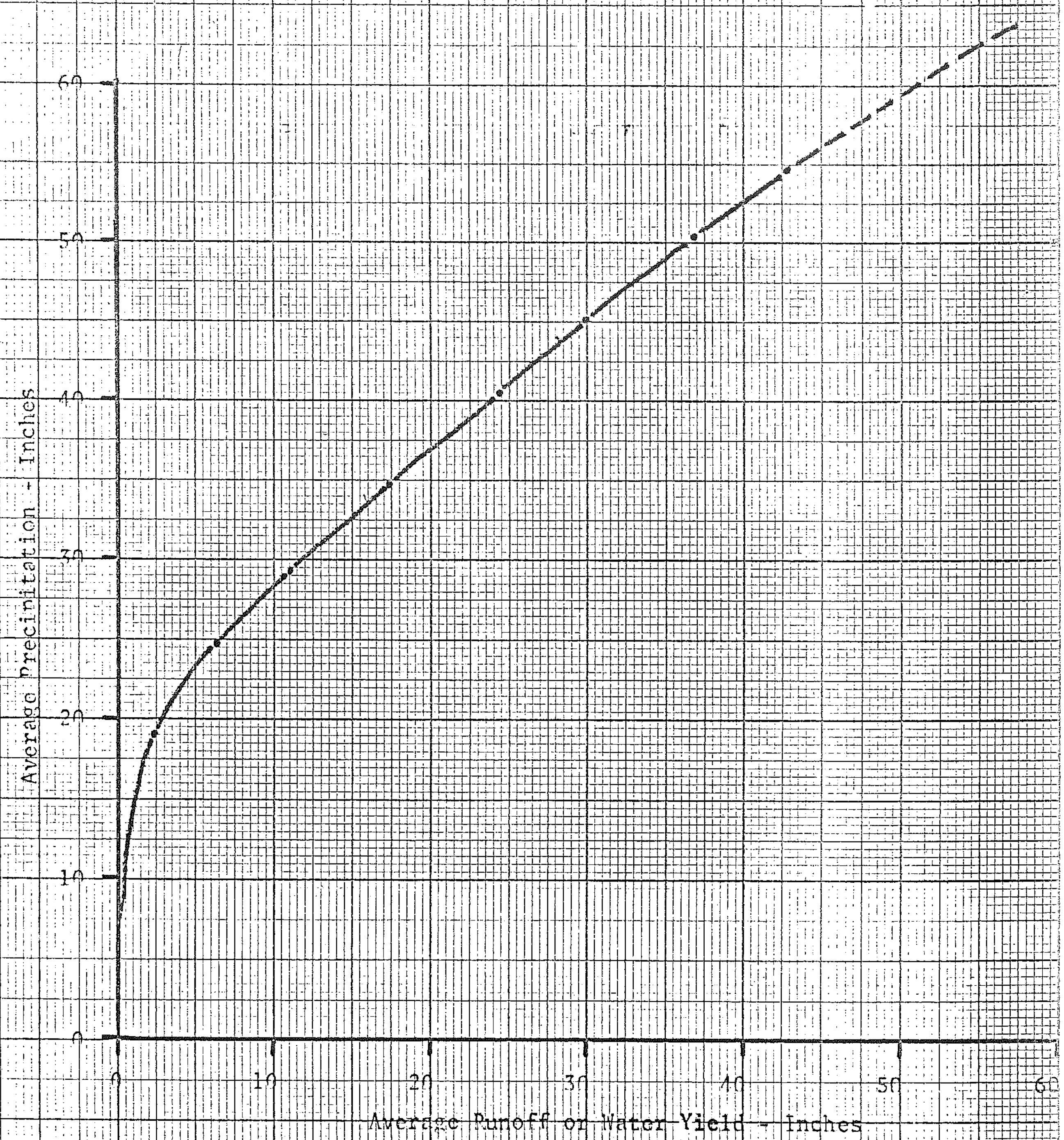
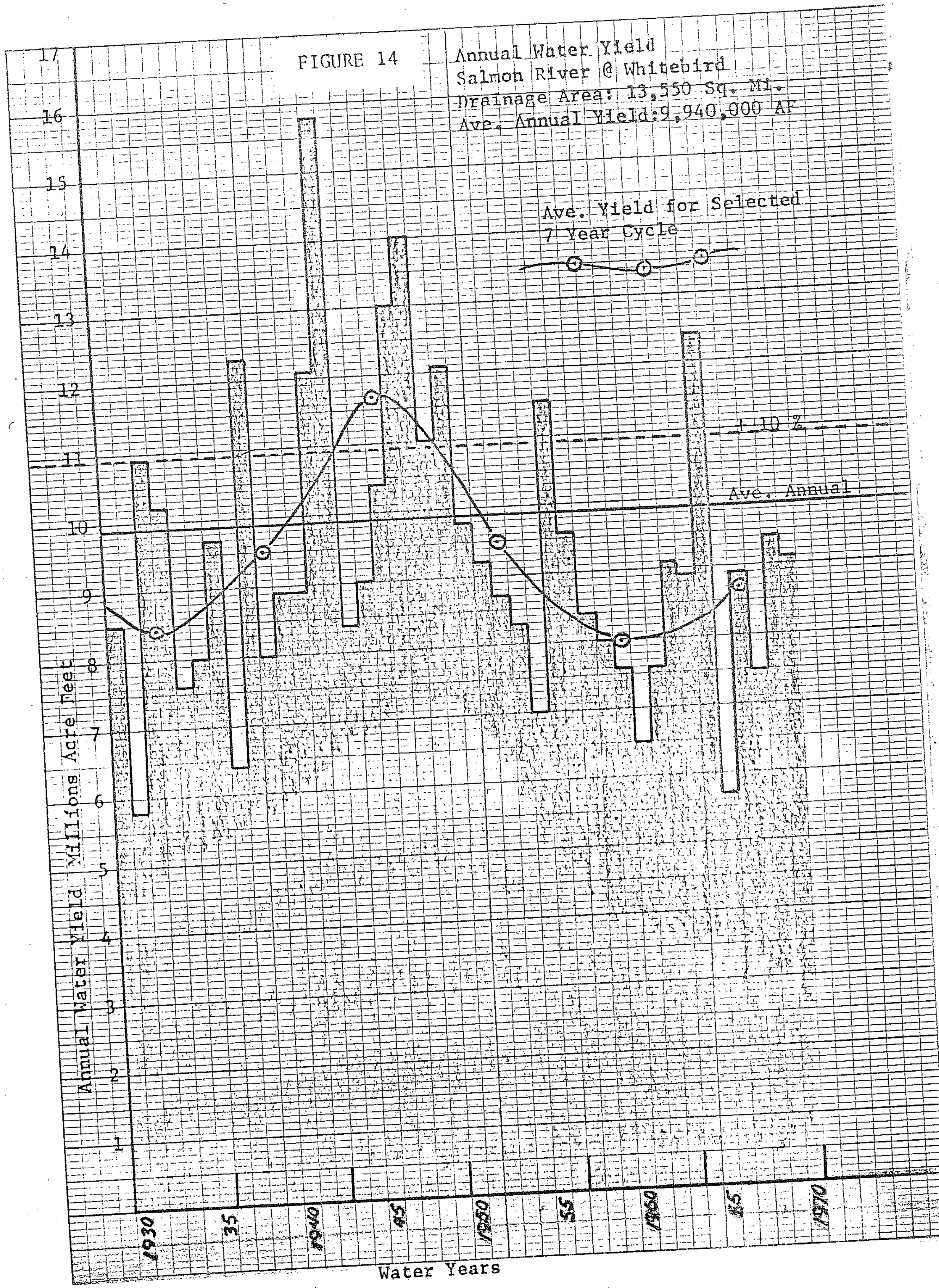


FIGURE 12. Water Yield Increase Factor ("F" value) by Elevation Zones. Based on an Analysis of Water Balance Data for the Nezperce National Forest.

FIGURE 13. Precipitation versus runoff for the Nezperce National Forest. From Water Balance calculations, after Thorntwaite.

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+ 10 %
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Water Years

The Captain John site (13-3160+90) would develop the remaining head upstream from the Freedom-Riggins site (the tailrace altitude of the Crevice site) by means of a diversion at altitude 2,140 feet in sec. 8, T. 23 N., R. 1 E., on the Little Salmon River, and in sec. 6 of this same township on Rapid River. The conduit on the Little Salmon River would be about five miles long and an additional two-mile-long conduit including an inverted siphon would join the Rapid River water near the mouth of Captain John Creek at mile 2.2, sec. 28, T. 24 N., R. 1 E. The tailrace altitude would be 1,845 feet and the drainage area would be 554 square miles.

The Freedom-Riggins site (13-3165+70) with damsite on the Salmon River in sec. 1, T. 26 N., R. 1 E., utilizes a damsite within the suggested maximum backwater limit of the Lower Canyon reservoir site (altitude 1,575 feet). To raise the water surface from its present altitude of 1,558 feet to the Crevice site tailrace altitude, 1,845 feet, a dam with a crest length of about 800 feet would be required. Head development would be between altitudes 1,575 and 1,845 feet. The drainage area is 13,320 square miles and the site is at river mile 69.3. If water is raised to this altitude, the town of Riggins would have to be relocated. The existence of the reservoir near the relocated town would be beneficial, however, and there are suitable relocation sites, possibly around the bay formed where the reservoir entered the Little Salmon River canyon, or at Shorts Bar a short distance up the main Salmon River from the present location.

The Lower Canyon site (13-3170+10) at mile 0.5, secs. 13 and 14, T. 29 N., R. 4 W., where the drainage area is 14,100 square miles is arranged to have the same tailrace altitude as High Mountain Sheep so that the China Gardens site may develop all of the head in both the Salmon and Snake Rivers. The maximum water surface altitude of Lower Canyon is 1,575 feet, the tailrace altitude of the Freedom-Riggins site. At altitude 1,575 feet the dam would have a crest length of about 2,100 feet. The Federal Power Commission (1964) mentions possibilities for developments of the lower Salmon River that will result from development of the High Mountain Sheep project on the Snake River upstream from the mouth of the Salmon River. The Lower Canyon dam is mentioned as being located at either mile 0.5 or at mile 3.7. A dam at mile 3.7 would have a crest length of less than 1,000 feet for a dam to altitude 1,575 feet. Possibility of a higher dam at Lower Canyon has also been mentioned.

Salmon River to Lewiston-Clarkston

The China Gardens site (13-3170+20) is at mile 172.5 on the Snake River where the drainage area is about 88,000 square miles. The damsite is in sec. 11, T. 31 N., R. 5 W., Boise Meridian, Idaho, and sec. 32, T. 7 N., R. 47 E., Willamette Meridian, Washington. A dam that would raise the water from its present altitude of about 832 feet above sea level to the High Mountain Sheep tailrace altitude of 915 feet (planned normal pool altitude is 910 feet) would be about 1,200 feet long at the crest. The tailrace will be limited to altitude 842.5 feet (845 feet for our purposes) by backwater from the planned Asotin reservoir. The Corps of Engineers' plan suggests a plant at the dam with an installed capacity of 180 MW. The site is 16 miles downstream from the mouth of the Salmon River.

The Asotin site (13-3340+10) at mile 146.8, sec. 36, T. 35 N., R. 6 W., Boise Meridian, and sec. 22, T. 10 N., R. 46 E., Willamette Meridian, Washington, where the drainage area is 93,100 square miles could develop the head between altitudes 735 feet at the damsite and 845 feet (842.5 feet according to the Corps of Engineers' plan) at the China Gardens site tailrace. The dam planned will be about 2,900 feet long, including the embankment section. Power installations ultimately will be 540 MW according to present plans. This is the most downstream powersite on the main stem of the Snake River from which potential waterpower is allotted to the State of Idaho. The project has been authorized for construction by the Corps of Engineers.

Clearwater River

The drainage area of the Clearwater River is about 9,600 square miles. This is 68 percent of the area drained by the Salmon River (14,100 square miles). Comparison of the average annual discharge of the two streams gives an approximately inverse ratio. Discharge records show the Salmon at Whitebird, drainage area 13,550 square miles, averaging 10,900 cfs for a 48-year period ending with water year 1960. This is 71 percent of the Clearwater River discharge at Spalding, drainage area 9,570 square miles, for a 38-year period ending in 1960, 15,260 cfs. Salmon River runoff per square mile is about 50 percent of that for the Clearwater River. The principal tributaries of the Clearwater River are the Selway River, its tributary Lochsa River, Middle Fork Clearwater River, North Fork Clearwater River, and Potlatch River. With the exception of the Potlatch these streams head near the summit of the Bitterroot Range and flow generally westward. The Selway Basin is adjacent to the Salmon River on the south and the North Fork Clearwater Basin is adjacent to the St. Joe River basin on the north. The Bitterroot River and the Clark Fork and their tributaries drain the opposite (eastern) slopes of the Bitterroot Mountains adjacent to the Clearwater River headwater streams.

The eastern portion of the Clearwater River basin is composed of rugged, heavily timbered mountains in which the various tributary streams have eroded deep canyons. The western part of the basin is generally barren and untimbered. The high benchlands are often adaptable to dry-farm wheat raising and the valleys, often irrigated from the creeks or by pumping from the river, produce hay and grain for livestock, as well as potatoes, many kinds of fruit, sugar beets, and so on.

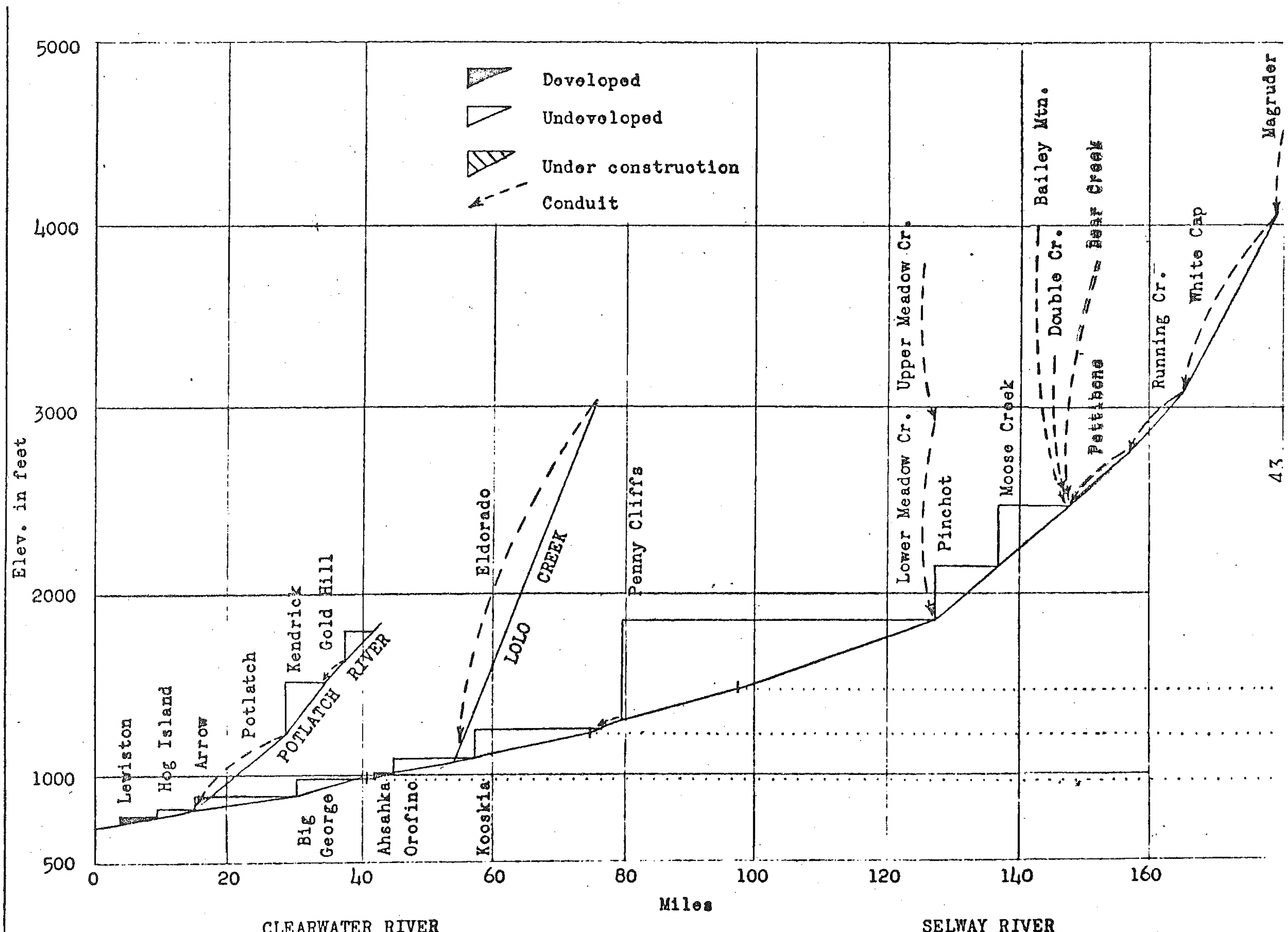
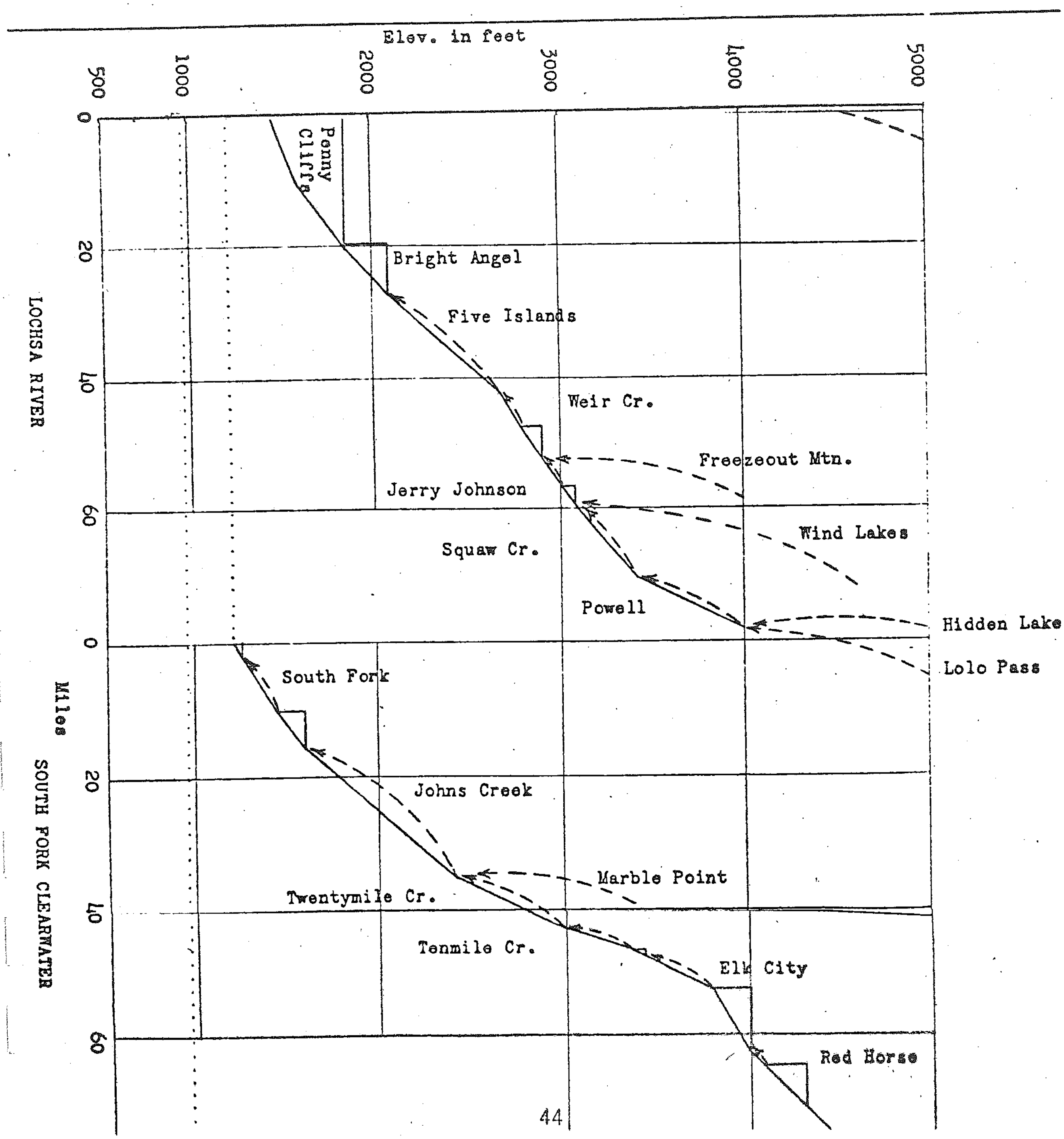


FIGURE 12.--PROFILE OF CLEARWATER RIVER AND TRIBUTARIES SHOWING DEVELOPED AND UNDEVELOPED POWERSITES


Elev. in feet
500
1000
2000
3000
4000
5000
LOCHSA RIVER
Miles
SOUTH FORK CLEARWATER
0
20
40
60
Penny Cliffs
Bright Angel
Five Islands
Weir Cr.
Freezeout Mtn.
Jerry Johnson
Wind Lakes
Squaw Cr.
Powell
Hidden Lake
Lolo Pass
South Fork
Johns Creek
Marble Point
Twentymile Cr.
Tenmile Cr.
Elk City
Red Horse

The timber on the South Fork is often lodgepole pine but timber quality improves to the northward being mainly yellow pine, fir, and tamarack in the Selway River basin, and white pine, cedar, spruce, hemlock, and fir in the Lochsa and North Fork basins. The Selway River is considered to be the main headwater stream and becomes the Middle Fork Clearwater River at its junction with the Lochsa River. The Middle Fork and South Forks join at Kooskia to form the Clearwater River. The Clearwater River flowing northwestward is joined by the North Fork, flowing southwestward, at a point about 40 river miles from the mouth. At this junction the Clearwater turns westward to its confluence with the Snake River at Lewiston. The following tabulation shows the relative size of the principal tributaries:

Selway River	2,000	square	miles
Lochsa River	1,180	do	do
S.F. Clearwater River	1,150	do	do
N.F. Clearwater River	2,440	do	do
Potlatch River	650	do	do

The Potlatch River heads at an elevation of about 5,000 feet and its drainage basin is principally in the barren western section just described. The river and its main tributaries have cut deep canyons in the basalt underlying the area.

The climate within the basin is influenced by the warm moisture-laden air moving eastward from the Pacific Ocean which causes heavy precipitation as it rises over the Bitterroot Mountains. Average annual precipitation varies between approximately 15 inches at the western edge of the basin to more than 70 inches in the mountains. The average for the basin is about 40 inches distributed throughout the year in a pattern similar to the Pacific Coast area, wet in winter and dry in summer. It would be very desirable to include storage with all waterpower developments undertaken in the basin and there are some good storage sites. Generally, however, the streams fall rapidly in deep narrow canyons and very high dams will be required to effect significant amounts of storage. Figure 11 is a planimetric map showing powersite locations and figure 12 contains longitudinal profiles showing the powersites used for determining the potential power of the Clearwater River basin.

Selway River

The Magruder site (13-3360+10) is planned to develop power from the runoff from 145 square miles of the Selway River headwater streams at a powerhouse at mile 179. The Selway River, Wilderson Creek, and Deep Creek are assumed to be divertible at an altitude of 5,000 feet and the water carried along the right bank of the Selway River to the Magruder ranger station where the altitude is 4,050 feet. The drainage basin is dotted with glacial (?) lakes and it is believed that the water supply would be relatively good during the low water period. About eight miles of conduit from Sweet and Wilderson Creeks and five miles from Deep Creek would be necessary.

The White Cap site (13-3360+20) on the Selway River, at mile 164.5, is at the diversion site given by Hoyt (1935, p. 346). The plan shown assumes diversion at the Magruder site tailrace on the Selway River where the drainage area is 280 square miles, and at altitude 4,050 feet on White Cap Creek where the drainage area is about 100 square miles--380 square miles in all. There is a reservoir site at the diversion point on White Cap Creek, and it would be necessary to raise the water surface 100 feet to establish the 1,000 feet of gross head. The conduit along the Selway River would be about 16 miles long and could pick up water from Indian Creek. The White Cap tailrace altitude of 3,050 feet is 15 feet higher than the present water surface to permit creation of a small pond at the Running Creek diversion site.

The Running Creek site (13-3360+30) consists of a powerhouse site on the Selway River at mile 157 where the water surface is 2,750 feet, and water would be carried to it from the White Cap site tailrace altitude of 3,050 feet in a seven-mile-long conduit. A diversion dam at mile 164.5 would raise the water surface from 3,035 to 3,050 feet. An additional three-mile-long conduit would add water from about 100 square miles of area drained by Running Creek. The total drainage area is 607 square miles.

The Bear Creek site (13-3360+40) with a powerhouse site at mile 3.6 on Bear Creek where the water surface altitude is about 2,750 feet would utilize water diverted at an altitude of 3,750 feet from Bear, Paradise, and Cub Creeks. A diversion about six miles long would be required on Bear Creek and an additional four-mile-long diversion would suffice for the Cub Creek and Paradise Creek diversions. The total drainage area is 140 square miles.

The Pettibone site (13-3360+50) would utilize a dam at about mile 147 to create head. The water surface altitude at the damsite is about 2,450 feet and a dam that would raise the water surface to an altitude of 2,750 feet would have a crest length of about 1,450 feet according to the 1924 river survey map prepared by the U. S. Geological Survey. The reservoir would largely replace the Goat Creek diversion and conduit development suggested by Hoyt (1935, p. 347). The drainage area is 915 square miles.

The Double Creek site (13-3360+70) shows head and potential power amounts that would accrue from the diversion of East Fork Moose Creek at mile 6.5, altitude about 3,300 feet, a short distance upstream from Battle Creek, and carrying the water in a conduit along the left bank of Moose Creek to a point about one mile downstream from Double Creek, at the backwater altitude of the Moose Creek reservoir site, 2,450 feet. The drainage area is 103 square miles. The conduit would be about seven miles long and would be shortened by three miles if the dam and reservoir were substituted. Approximately the same potential power with a storage reservoir added could be realized by constructing a dam downstream from the mouth of Elbow Creek to raise the water to the 3,300-foot contour altitude. The drainage area could be increased to 147 square miles as it would include 44 square miles from Battle, Elbow, and Monument Creeks. The diversion-conduit plan is used here because the Moose Creek reservoir site immediately downstream may make another storage reservoir unnecessary.

The developed Moose Creek Ranch powersite (13-3360+72) (Federal Power Project 2353) in unsurveyed sec. 25, T. 33 N., R. 12 E., was formerly licensed as Project 1996. The project consists of a concrete diversion dam 6 feet high and 108 feet long, a 97-foot flume, a frame powerhouse, and a 33 horsepower wheel operating a 24 kva generator. Altitudes and drainage area were not given.

The Bailey Mountain site (13-3360+75) would divert North Fork Moose Creek at an altitude of about 4,000 feet near the mouth of West Moose Creek and carry the water about six miles along the left bank of North Fork Moose Creek to the backwater limit of the Moose Creek reservoir site, 2,450 feet. The powerhouse could be on North Fork Moose Creek or, by a very short tunnel addition to the conduit, a single powerhouse could serve both the Moose Creek and Double Creek plants. The drainage area is 58 square miles and could be increased to 108 square miles by a four-mile-long conduit and inverted siphon to bring water from Wounded Doe and Lizard Creeks.

The Moose Creek site (13-3360+80) assumes the construction of a dam on the Selway River about 0.4 mile downstream from Divide Creek, at mile 137, where the drainage area is 1,200 square miles and the water surface is 2,150 feet. At altitude 2,450 feet water would back about five miles up Moose Creek and 10 miles up the Selway River to form a reservoir with a capacity of 222,000 acre-feet. The dam would have a crest length of about 800 feet. The Hopewood Creek and Goat Mountain sites suggested by Hoyt (1935, p. 347) are in this section of river.

The Pinchot site (13-3360+87) on the Selway River at mile 127, where the drainage area is 1,330 square miles, is planned to develop the head between the Moose Creek site tailrace altitude of 2,150 feet and the Penny Cliffs site backwater limit altitude of 1,855 feet. The Pinchot site is in the original Jim Creek reservoir site that had a dam planned at altitude 1,840 feet, which is now included in the Penny Cliffs reservoir site. The Jim Creek reservoir site upstream from the Penny Cliffs backwater limit is included in the reservoir that would be formed by constructing the dam near Pinchot Creek. The 1924 river survey indicates that the best cross section would be about 1,000 feet upstream from the creek where the dam would have a crest length of about 1,000 feet at altitude 2,150.

The Upper Meadow Creek site (13-3360+90) with a powerhouse site on Meadow Creek at about mile 19, would utilize water diverted from Meadow Creek at an altitude of 3,800 feet by means of a conduit about eight miles long along the right bank of Meadow Creek to altitude

2,900 feet. The drainage area is 90 square miles and water from an additional 23 square miles could be added by means of a diversion from streams draining the south side of Little Copper Butte in a three-mile-long conduit to the above-described powerhouse site.

The Lower Meadow Creek site (13-3360+95), by diverting Meadow Creek at the Upper Meadow Creek site tailrace altitude of 2,900 feet and a 10-mile-long conduit along the right bank of Meadow Creek to the backwater limit from the Penny Cliffs site, 1,855 feet, could develop the head remaining on Meadow Creek. The powerhouse site is at mile 2.4 and the drainage area is 177 square miles.

The Penny Cliffs site (13-3370+20) as studied by the Corps of Engineers would have a dam located at mile 79 on Middle Fork Clearwater River where the drainage area is 3,310 square miles. A dam that would raise the water from its present altitude of 1,285 feet to an altitude of 1,855 feet would have a crest length of about 1,800 feet. This site would include the Three Devils site as well as the Jim Creek, Meadows, Selway Falls, and Rock Cliff sites on Selway River as well as the Split Creek site on the Lochsa River (Hoyt, 1935, p. 348). The plan and profile of the Middle Fork Clearwater River surveyed in 1924 shows the water surface altitude at the damsite to be about 1,285 feet above sea level. Head to altitude 1,260 feet would be developable by means of a tunnel and penstock system through the left abutment, or by a means of a reregulating dam and separate powerplant at the Kooskia site backwater limit, altitude 1,260 feet. The tailwater might be as low as 1,245 feet in an actual development in order to limit flooding in Kooskia by the next downstream site.

South Fork

The Red Horse site (13-3370+30) might be developed by means of a dam on the Red River at altitude 4,100 feet in unsurveyed sec. 7, T. 28 N., R. 9 E., where the drainage area is 135 square miles, to raise the water surface to an altitude of 4,300 feet, and a conduit four or five miles long to altitude 4,000 feet in sec. 3, T. 28 N., R. 8 E. The project would be entirely on the Red River which, together with American River, forms the South Fork Clearwater River at a point about 1½ miles downstream from the powersite and about the same distance southwest of Elk City. The site should be investigated for its upstream storage possibilities as there are few reservoir sites on the South Fork, which flows principally in a narrow canyon that must also be used for a road from Elk City to its mouth. The damsite would be located in the section of Red River upstream from Red Horse Creek. Topographic maps of the area are not suitable for determining the capacity of the reservoir site.

The Elk City site (13-3375+10) would also be a combination dam and conduit developing 200 feet by a dam at an altitude of about 3,800 feet in sec. 28, T. 28 N., R. 7 E., where the drainage area is 341 square miles. A conduit about five miles long on the right bank of the South Fork would carry the water to the powerhouse site near the mouth of Tenmile Creek (mile 47). The water surface at the powerhouse site is at an altitude of 3,420 feet and, according to the land net on the Nez Perce National Forest map, the powerhouse site would be in unsurveyed sec. 35, T. 28 N., R. 6 E.

The Tenmile Creek site (13-3375+20) with a diversion dam at mile 46.5, where the drainage area is 496 square miles, would raise the water surface from its present altitude of about 3,400 feet to the Elk City site tailrace altitude of 3,420 feet and develop the remaining head to altitude 3,000 feet in a conduit a little less than five miles long. The powerhouse site would be at the mouth of Twentymile Creek, mile 42.8, in unsurveyed sec. 31, T. 28 N., R. 6 E., as shown on the Nez Perce National Forest map.

The Twentymile Creek site (13-3375+50) is visualized as having a diversion dam at mile 42.5 near the tailrace of the Tenmile Creek site, drainage area 532 square miles, and a conduit 7½-miles long to mile 35, unsurveyed sec. 30, T. 29 N., R. 5 E. Head would be developed between altitude 3,000 and 2,400 feet. Hoyt (1935, p. 352) suggests a flume down the right bank connecting the above points. It probably would also be worthwhile to collect low-water discharges from several tributary creeks in that reach of river during low-water periods.

The Marble Point site (13-3375+60) would utilize water from 85 square miles of Johns Creek drainage. The diversion would be approximately in unsurveyed sec. 31, T. 28 N., R. 5 E., and a 6½-mile-long conduit would lead to the powerhouse site at the mouth of Johns Creek, mile 35 on South Fork Clearwater River in unsurveyed sec. 30, T. 29 N., R. 5 E. Head would be developed between an altitude of 3,400 and 2,400 feet. Perhaps the powerhouse for Twentymile Creek site could be shared.

The Johns Creek site (13-3375+80), because of difficulty in locating a conduit on the canyon walls and because of a large bend in the river, is suggested for development by a diversion dam at the mouth of Johns Creek, mile 35, where the drainage area is 728 square miles, and an eight-mile-long tunnel to a balancing reservoir site on Lightning Creek from which the water would be dropped in a 1½-mile-long penstock to a powerhouse site at altitude 1,615 feet, mile 15.6, sec. 9, T. 30 N., R. 4 E. As described here the Johns Creek site includes the Sheep Bridge site as well as a reach of river formerly developed by the Grangeville plant as suggested by Hoyt (1935, p. 532).

The Grangeville site (13-3380) would not be redeveloped. The Grangeville Plant of the Washington Water Power Company was constructed in 1917 and used until recent years. The company surrendered the Federal Power Commission license and dismantled the dam and plant in 1963. This reach is now included in the Johns Creek site just described. **

The South Fork site (13-3380+10) might be developed by means of a dam at mile 9.4, sec. 17, T. 31 N., R. 4 E., where the water surface altitude is 1,435 feet. A dam that would raise the water to an altitude of 1,615 feet would have a crest length of about 700 feet. An eight-mile conduit on the right bank of the South Fork would carry the water to the Kooskia site backwater limit altitude of 1,260 feet. The South Fork as described here probably would best be developed in two units; a powerhouse at the South Fork dam and rediversion of the water to a powerhouse at the Kooskia site backwater limits at mile 1.3, sec. 8, T. 32 N., R. 4 E.

South Fork to North Fork

The Kooskia damsite (13-3390+10) is suggested for development at mile 57.2, on the Clearwater River, sec. 36, T. 35 N., R. 2 E., where the Clearwater River drainage area is 4,944 square miles. The site as here proposed would have a backwater limit of 1,260 feet, the Penny Cliffs tailrace. A lower backwater limit might be desirable (refer to the Penny Cliffs discussion). The water surface at the damsite is about 1,086 feet. At altitude 1,260 feet the highway, railroad, and town of Kamiah will have to be relocated. There will also be some relocation expense in and around Kooskia. The Penny Cliffs-Kooskia arrangement for developing this reach of river seems to be necessary because of the location of the town of Kooskia. The Kooskia damsite is suitable topographically and geologically for a dam that would raise the water to an altitude of 1,600 feet and form a reservoir with a storage capacity of 5,670,000 acre-feet. Opposition from the affected area made it evident that the site has social and economic infeasibility and it has been eliminated from the Corps of Engineers 308 report. A dam to altitude 1,600 feet would have had a crest length of about 1,350 feet. At an altitude of 1,260 feet the crest length is reduced to about 550 feet.

APPENDIX

PART 5

RELATIONS OF VEGETATION TO WATER QUANTITY

How Much Water in One Inch of Rain ?

An inch of rain falling evenly on one acre of ground is equivalent to about 27,205 gallons of water, according to hydrologists of the U.S. Geological Survey.

Here's how its determined: One inch of rain falling evenly over 1 acre of ground would amount to a total of 6,272,640 cubic inches of water. A cubic foot of water weighs about 62.43 pounds. Therefore, the weight of a uniform fall of 1 inch of rain over 1 acre would be about 226,621 pounds, or 133.3 short tons. Consequently, a rainfall of 1 inch over 1 acre would mean about 27,205 gallons of water.

1. National Forest lands produce 66% of the water in the Columbia Basin and 30% of the water in the Missouri Basin.

2. All forested watersheds (including private lands) contribute three-fourths of the nation's water but only occupy one-third the land.

3. There are 465 cataloged PWI watersheds in Region 1; 72 of these are municipal watersheds.

4. R-1 municipal watersheds contribute water directly to 25% of Montana's population, 17% of North Idaho's population and to approximately 2,000 people in eastern Washington. This represents 105 million gallons of use every day. At this rate, it is like drinking Georgetown Lake (near Philipsburg, Montana) dry four times each year.

5. Nationwide, the Forest Service provides water from municipal watersheds to 1100 communities, or 17 million people.

6. A rough tally indicates R-1 municipal watersheds have a total annual allowable cut of 28,000 MBM. This is about 1.9% of the Region's annual allowable cut of 1.5 billion B.F. It's obvious why we can't lock these drainages up and devote them to single use.

Items relating to vegetation and water quantity

1. From standpoint of microclimate, large expansive areas should be avoided.

2. Most benefits derived from a pattern of small openings protected by tree blocks or belts in an irregular pattern of curves of flowing lines. Semi-geometric patterns may be necessary for protection against wind and solar radiation.

3. Size of clearings or openings should always be specified in relation to height of trees to windward and to sunward (in H units) that provide protection to the exposed site.

4. Must manipulate the timber harvest to receive and dispose of "X" number of acre feet of water-per-acre per year.

5. In Austrian Alps an ultimate density of 3,000 trees per hectare (2½ acres) is sought. It is not yet known whether this density will suppress all avalanches.

6. Plant communities, soil types, microorganisms, animal life and the ecological relation of wind, snow, and thaw patterns all show definite interrelationships. (Austrian Alps L. F. 12/67).

7. Time of peakflow is advanced when size of clearcut area is greater than 30 times the height of adjacent standing trees.

8. Removal of woody vegetation results in an annual increase in water yield, usually measured as streamflow if the amount removed is significant.

9. There is an inverse relation between tree density or tree mass and snow accumulation. Greatest acculululation of snow is in small openings in forest and the least under dense forest canopy. Clearcut openings must be fitted to the landscape to produce a favorable microclimate.

10. Harvest trees in successive narrow strips at right angles to the maximum solar radiation to produce a "wall-and-step" pattern with the wall to the south and the steps to the north. This would provide the most shade to the snowpack and reduce reradiation from trees to the north.

11. Cut L-shaped openings on east and west-facing slopes so that cold air drainage is trapped in the contour leg of the "L".

12. Clearcutting will not have the same effect in second growth as in virgin stands of timber. Future yields of water will depend on the vegetation occupying the watershed at any given time - not on the quantity of vegetation originally removed.

13. Long yarding distances made possible with balloon logging allow logs to be hauled to roads along ridgetops or downslope to roads on the contour. It can appreciably reduce road construction and maintenance and reduce damage to soil, remaining vegetation and watercourses.

14. Where demand for more water yield is great and wood production is not paramount, small openings might be converted to grass or other smaller stature, shallow-rooted plants for permanently increased water yields. Those species that require less water and have less extensive root systems should be favored along the border between forest and openings. Depletion of soil moisture may extend as far as one-half to two or even three tree heights into the openings, depending on species.

15. Breaking up mass of brush vegetation along watercourses, benches, and gentle slopes with deep soils to complement existing firebreaks along ridgetops, can reduce chance of major fires, provide improved habitat for wildlife, possibly provide winter recreation and increase water production.

16. On steeper slopes, it may be possible to replace brush with low-water consuming plants in narrow strips on the contour. Desiccants, prescribe burning, herbicides and mechanical treatments are proven means.

17. Reduction of vegetation following wildfires offers a good opportunity to convert the most favorable sites to grass; however, continued protection and maintenance are needed for permanence.

18. Ways that water yield from forested areas might be increased by reducing the vegetation and/or root mass or by rearranging the vegetation pattern and structure are:

a. Temporary - short-lived improvement without additional treatment.

(1) Thin pole-size stands.

(2) Cut patch or strip openings in pole stands for pulpwood.

(3) Harvest sawtimber so that the future yield of water is favored over wood production.

(4) Create openings in sawtimber canopy by group selection.

(5) Prune sawtimber heavily.

b. Permanent - long-lived improvement with retreatment or followup.

(1) Change arrangement of tree canopy.

(a) Convert uneven-age stands to even age.

(b) Favor species that require, consume, and lose the least water (slow-growing species).

(c) Change the structure (wall and step, L-shape openings, etc.)

c. Convert to low-growing, low water-consuming species in small openings or narrow strips (grass, prostrate shrubs, and carpet vegetation).

(1) On riparian and moist sites.

(2) On relatively stable land slopes.

d. Remove or kill understory woody vegetation - particularly deep and extensively rooted plants.

19. Evaporative losses of intercepted winter snow appear to be a less important factor influencing streamflow in the subalpine forest than previously thought.

20. Aerodynamic processes involving transport of snow through and from the forest canopy to the site of final deposition deserve emphasis. Redistribution of snow as a result of creating openings in forest stands may be a major factor influencing water yield. If so, knowledge of airflow and snow transport in the forest canopy and/or the effect of size, spacing, orientation and total amount to openings on snow accumulation is basic to watershed management in subalpine forests.

21. A small watershed is sensitive to high-intensity rains of short duration and to forest land use.

22. In California they found that in strip cutting only about one-half the difference in snow between a cut opening and the adjacent forest was found in the opening itself, the rest being found in the adjacent forest.

23. Temporary benefits in total water yield and long-term benefits in delayed yield may be expected from conversion of brushland to forest.

24. Excesses of Snow Water Equivalent, in Inches, Associated with Cutting Compared with Uncut Forests Yuba Pass, California

Date & area considered	Excess of snow associated with treatment				
	Slash piled	Slash lopped	Small trees left	Slash dozed downhill	Wall-and-step[1/]
4/24/63:					
Cut strip only	4.4	6.4	8.0	14.4	18.9
Whole forest	1.1	1.6	2.0	3.6	4.7
5/21/63:					
Cut strip only	7.2	7.2	-5.2	-1.2	13.2
Whole forest	1.8	1.8	-1.3	-0.3	3.3

1/ In wall-and-step cutting, one-fourth of stand was clearcut with slash bulldozed down to the lower edge; in an equal width to the north, the taller trees were removed. In the other cuttings, only the strip was cut.

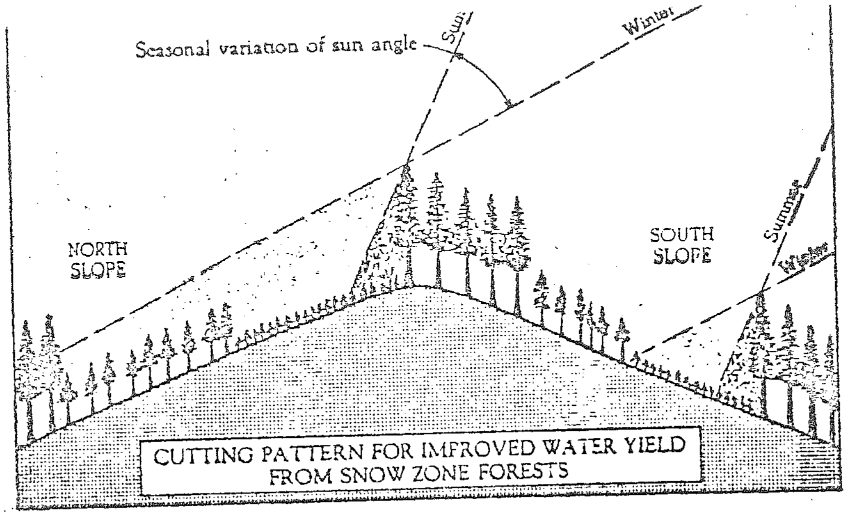


Figure 3. Wall-and-step forest for maximum snow accumulation and delaying melt.

26. Generally, the heavier the cut, the greater the increase in yield. The increase seems to be related more closely to the amount cut than to the amount left.

27. Maximum water savings may be obtained by removing vegetation that transpires at the full potential rate.

28. A cutting pattern or manipulation of vegetation, such as the piling of slash and the creation of barriers to trap cold air at the downward end of cut strips, particularly on north slopes, will favor accumulation and prolongation of melting.

29. "Wall-and-step" strip cutting - Strips should be oriented east to west on north and south slopes, northeast to southwest on east slopes, northwest to southeast on west slopes. Successive cutting would proceed generally southward. (Also see No. 31.)

30. Short cutting cycles are desirable for maximum water yield.

31. Strip Orientation: (Intolerant Species)

South slopes - northwest to southwest.
North slopes and level areas - east and west.
East slopes - L-shaped units with arms extending north and west.
West slopes - L-shaped units with arms extending north and east.

Width of Strips - One to two tree heights.

Cutting Plan - Successive strips cut from north toward south.

32. A clearcut condition, from a hydrologic standpoint, will persist until the regeneration reaches sufficient height above the average snow depth to cause increased interception and evaporation. This means that the vegetation will have to be at least two times the average snow depth which will require at least 15 years in this Region. Leave blocks could be replanned for cutting on this same basis after the initial sale has been recovered hydrologically.

33. Cutting of forest stands having forest canopy densities of 50-70% and volumes of 8-12 M bd. ft. per acre will quite probably increase maximum snowpack water accumulation by at least 1/3 and increase snowmelt rates by at least 1/2 the amounts in similar uncut stands.

34. Losses from riparian use along the banks of the Farmington Creek in Utah have amounted to 1/3 of the total streamflow from August to October.

35. Maximum moisture use is probably approached in most well-developed forest stands with dense understory.

36. Removal of dense laurel and rhododendron on an entire watershed in the southern Appalachian hardwoods resulted in an immediate increase of 3.6 inches in water yield.

37. Colorado experiments showed that increased storage of snow in cut areas was accompanied by increased rate of melting and some increase in evaporation. As a result, snow accumulated in the cut areas disappeared about the same time as snow in uncut areas. Melt water from snow stored in openings appeared in the streams about the same time as snow melt water from uncut areas.

38. Management applications - we must know what processes we are attempting to control, when increases of flow will occur, how long they will persist, what areas should be treated and what kinds of vegetation should be developed.

39. If water yield is the primary goal in noncommercial forest areas, conversion to herbaceous vegetation might be a feasible management objective.

40. Riparian cuttings offer possibilities for localized increases in streamflow in situations where quick response is needed.

41. At Coweeta, all trees less than 15 feet above the stream channel were cut, leaving a cleared strip along the channel. During 10 days following cutting, water yields increased 12%. Similar cuttings in San Dimas, California increased flow and changed stream from an intermittent to a perennial flow.

42. Gains in water yield are offset to some extent by increased evaporation from the stream and that warming of the water favors development of algae and may destroy fish habitat.

43. In 30 experiments in U. S., Africa and Japan, changes in water yield after cutting averaged about eight inches following elimination of fully stocked stands and about the same decrease 20 or 30 years after forestation. (Recovery period.)

44. (Hoover 1966) It is not yet clear whether the major effect on annual yield increment in snow country is due to reduction in interception loss of snow, or less transpiration after cutting, or whether snowpack depth is increased by more effective trapping and shielding of snow from evaporation.

45. Yield increases are reproducible and fairly independent of annual climate.

46. Annual recuts will not maintain maximum yield but about 2/3 of maximum can be sustained. Repeated cuttings on moist sites tend to develop vigorous green crop of low vegetation which regains part of the evapo-transpiration potential of full forest cover. There seems to be a point of diminishing returns in the struggle to sustain the increase obtained after the first year after cutting.

47. Cyclic cutting may be possible on alternate working compartments planned to produce wood on the best sites and extra water on others.

48. Choosing forest areas to manage for maximum water may also involve the choice of aspect of the watershed. Greatest yield - north slopes.

49. There is very little evidence that cutting at higher elevations has less effect on water yield, except insofar as average rainfall, usually related to elevation, controls the available water.

50. Ideal way to combine wood and water production is to limit most evaporating plant surfaces and volumes to fast-growing species producing high-quality wood.

51. Studies at Priest River Experiment Station in WP type (after four years) showed an increase of about 4.2 inches in the maximum amount of snow-pack water when dense forest stand is clearcut. Also found that snow water content was affected uniformly by changes in the forest canopy regardless of elevation, aspect, or magnitude of snowfall.

52. Studies in Michigan showed that the mean water content of the snowpack at the time of maximum accumulation was nearly two inches greater under deciduous forests than under pine (for two years of study). In mixed pine-oak stands the difference was approximately midway between the other two.

53. Studies made in April-May, 1968 on Gallatin Forest by Watershed Management and Timber Management jointly, in Bear Creek and Squaw Creek, resulted in an average water content increase of 45.6% between cut and un-cut blocks. Measurements were taken on various slopes, aspects and ele-vations. Readings were made in the cutover blocks and in the adjacent un-cut timber.

54. Increased runoff from Fool Creek watershed in Colorado shows no signs of diminishing 11 years after experimental cuttings (alternative strips). Bonus each year averages enough to cover the Fool Creek watershed with four inches of water.

55. Best gains in streamflow are obtained in areas where deep-rooted vegetation can be removed. Aspen roots extend to depths over nine feet in high elevation watersheds. As much as five inches of moisture can be conserved in the upper six feet of soil by aspen removal.

APPENDIX

PART 6

FACTORS EFFECTING SNOW ACCUMULATION AND MELT

Factors Affecting Snow Accumulation and Melt

Researchers have been interested in the influence of the forest on snow for quite some time, but not until relatively recently has this influence been clarified and the influence of other variables investigated. Even less is known about the inter-relationships of forest variables with other variables such as elevation, aspect, slope, solar radiation, and other meteorological factors.

The effect of elevation on snow is to increase accumulation and to decrease melt rates (Packer 1960, 1962; Anderson 1963). A one- to two-inch increase in snow water equivalent per 100 feet rise in elevation was observed by Anderson, while Packer found that water equivalent increased quadratically with elevation.

Slope and aspect are two other topographic factors that influence snow accumulation and melt, mainly through their influence on intensity of radiation received and exposure to winds. South slopes will have a high rate of oblation because of a greater intensity of radiation and also a decrease in albedo (Goodell 1959). Packer (1960, 1962) observed that the relation of water equivalent to aspect was quadratic. Slope and aspect effects were best measured and expressed in combined form as solar radiation received at the surface. (Anderson 1963)

Another topographic factor mentioned by Anderson (1963) is curvature: ridge versus slope versus valley bottom. He found that ridge tops accumulated less snow than valley bottoms, which was probably due to a greater rate of evaporation and wind blowing the snow from the ridges. Also, snowmelt was 20 percent faster on the ridges than in valley bottoms.

The forest affects snow accumulation and melt by intercepting snow and by influencing meteorological factors such as insolation and wind patterns. Packer (1960, 1962) observed that snow water equivalent increased uniformly 4.2 inches as forest density decreased from 100 to 0 percent. This relation occurred regardless of differences in year, elevation or aspect; therefore, he inferred that this increase in water equivalent was due primarily to interception. An increase in forest density decreased snowmelt rates (Horton 1945). Lull and Rushmore (1960) plotted snow accumulation and melt against canopy closure and found that water equivalent decreased one-third of an inch for each 10 percent increase in canopy closure, while snowmelt decreased 0.005 inches per degree day for each 10 percent increase. These findings suggest that snow accumulation and melt are linearly related to forest density, which may not be the case as pointed out by Anderson, Rice and West (1958a) indexed trees to the south by the shade they produced and trees to the north by the ratio of tree height to distance of the tree from the sampling point. They found that shade from the south was related curvilinearly to maximum snow accumulation. Maximum accumulation occurred at 65 percent shade, decreasing on either side of this value. Both of these variables were significant for accumulation and melt periods, explaining 56 percent of the variation of the snowpack and 40 percent of the melt.

A few studies have been aimed at evaluating the inter-relationships of the above factors and determining their relative importance. Anderson and Paganhart (1957) found that elevation, solar radiation, and forest variables, in that order, caused the greatest difference in snowpack accumulation. Differences in snowmelt, in inches per degree day above 35 degrees, were best explained by shortwave radiation received, exposure of the snow course (azimuth direction in which there is no elevation higher than the course), and density of the forest within one-quarter of a mile to the south. No deviations from linearity were detected.

Vegetation variables have been found to be of less importance than topographic and climatic variables. Anderson, Rice and West (1958b) found wind and shade effects to be dominant in controlling snow accumulation in forest stands near openings. Packer (1960) tested snowfall years, elevation, aspect, canopy density, and their interactions as variables in a curvilinear multiple regression. He found that snowfall year x elevation and aspect x elevation were the only two significant interactions; canopy density had the least effect on snow water equivalent. All of these variables explained 91.6 percent of the variation.

Anderson (1967) investigated snow accumulation and its relationship to meteorological, topographic, and forest variables. Storm characteristics were found to explain almost all of the variation in snow accumulation, with the solar radiation and advective heat variables explaining the next greatest variation. Wind influenced the distribution of snow among openings, margins, and forest. Forest margins and openings had the greatest response to storms of different wind velocities. Natural shading effects reached a maximum in openings on high-energy south slopes. The increase in snow accumulation associated with differences in shading averaged 3.8 inches for south slopes and 1.9 inches for north slopes.

In forest stands differences in shading from 61 to 100 percent were associated with increases in snow of 1.7 inches on average-energy slopes, 2.1 inches on low-energy slopes, and 1.1 inches on high-energy slopes. Back radiation effects from trees to the north were small except for openings. Back radiation reduced snow by 0.3 inches on north slopes, 1.3 inches on the average slope, and 2.5 inches on south slopes. The effect of back radiation in forest and forest margins was less than 0.4 inches. All parts of the forest showed a response to differences in energy received. Low-energy slopes had more snow than high-energy slopes, but this effect was not as great as for slopes within the forest.

Few such studies have been conducted in the arid Southwest, where the climate is much different from other snow zones in the West, and where snow is limited to the higher elevations surrounded by warmer, drier air. In Arizona, some studies have been conducted in ponderosa pine stands on the Beaver Creek Watersheds near Flagstaff. A sapling and small pole stand of ponderosa pine on a Beaver Creek watershed contained the most snow prior to runoff, while an even-aged, large sawtimber stand contained the least amount. An uneven-aged stand containing saplings, poles and sawtimber was intermediate in retaining snow. Melt in an uneven-aged stand of 85 square feet per acre was not significantly different from that of an uneven-aged stand of 135 square feet per acre or from that of the sapling and pole stand of 65 square feet per acre. However, the melt rate directly adjacent to the canopy edge was one-half that in the open, the melt rate increasing with distance from the edge of the canopy and reaching a constant at two tree heights from the edge (Ffolliott, Hansen, and Zander 1965).

Ffolliott and Hansen (1968) observed that water equivalent increased from 1 to 7 inches as timber stocking decreased from 250 to 25 square feet per acre. This relationship held on all aspects and elevations. More snow accumulated at higher elevations, indicating more precipitation and lower temperatures. Water equivalent increased linearly from less than 2 to 6 inches with an increase in elevation from 6,800 to 7,300 feet. No apparent relationship was found between elevation and timber stocking. Little relationship was found to exist between insolation and other variables. Snowmelt rates were relatively uniform on the study area and were not significantly related to tested variables affecting accumulation.

In general, studies in the West, including some conducted in Arizona, indicated that climatic and topographic factors are the most important in explaining snow accumulation and melt, while forest factors played a lesser part. The effect of the forest on snow accumulation and melt and its inter-relationship with other variables affecting snow are of interest to the land manager since the forest is the one factor that can be changed by management practices.

Definitions (from Pacific SW Water Study, R-5)

Hydrologic Area - These are groupings of geomorphic types, geology, climate, soils, vegetative cover and potential, erosion and sedimentation characteristics that are relatively homogeneous. They contain groups of hydrologic response units.

Hydrologic Response Unit - A homogeneous unit within a hydrologic area that represents strong uniformity in geomorphic, geologic, climatic, hydrologic soil group, vegetation and vegetative potential, erosion and sedimentation characteristics.

Silting of Reservoirs

A nationwide study of representative reservoirs in the 1930's indicated a rapid decline in storage space because of silting. Reservoir life expectancy was based on no value after 80% of the storage space was lost:

39% of the reservoirs studied had an expected life of less than 50 yrs.
25% " " " " " " " " " from 50 to 100 yrs.
21% " " " " " " " " " " 100 to 200 yrs.
15% " " " " " " " " " over 200 yrs.

Rehabilitation by removal of silt by dredging or flushing cost from five to fifty times the original cost of installation.

Acres Required for Rights-of-Way of Various Widths

Width in Feet	Acres per Mile	Acres per 100 ft.
10	1.21	.023
20	2.42	.046
25	3.03	.057
30	3.64	.069
40	4.85	.092
50	6.06	.115
60	7.27	.138
70	8.48	.161
75	9.09	.172
80	9.70	.184
90	10.90	.207
100	[illegible]	[illegible]

* From: "Soil and Water Rehabilitation - Sullivan Cutoff and East Little North Fork Wildfire, Kootenai National Forest (9/70)."

Next time you take a break, pick up a few empty 3 lb. coffee cans - double end cut one (#1), single cut the other (#2) and add one six inch ruler to each. Place can #1 (without ends) firmly on soil to be tested. Put measured amount of water into the other can (#2), and then pour the measured quantity into can #1. Record how long it takes water or portion of water to be infiltrated. This kind of data will help support your hydrologic analysis recommendations - might even help you win a few battles.

Percolation - Infiltration *

A total of thirty (30) percolation tests using an 8" diameter ring container were run on the Sullivan and N. Fork burns. There did not appear to be significant infiltration variations between burns. Rather, the intensity of burn, compaction, and dryness of soil were the parameters effecting percolation and infiltration rates. The following infiltration rates, based on Laminar flow, are higher than caused by natural rainfall due to raindrop impact, slope, and puddle effects.

Infiltration Rates

	Site Condition	Mean Infiltration
A	Unburned areas - (adjacent)	
	1. Heavy Duff - Forest cover	180"/hour (theoretical)
	2. Below Duff - Forest cover	60"/hour
	3. Clearcut & burned - Grass cover	20"/hour
B	Inside burn - wetted surface	8.5"/hour
C	Inside burn - 4" deep - dry soil	2.0"/hour
D	Fire lines	1.5"/hour
E	Temporary log roads	.25"/hour

Possible return frequency for different size summer storms of various durations. U.S.W.B. Tech. Paper 40, 1961, "Rainfall Frequency Atlas of the United States."

Size Storm	Duration	Return Period
.25	30 min.	1 yr.
.50	30 min.	10 yrs.
	1 hr.	5 yrs.
1.00	1 hr.	50 yrs.
	2 hrs.	10 yrs.
	6 hrs.	2 yrs.
1.50	2 hrs.	50 yrs.
	6 hrs.	10 yrs.
	12 hrs.	5 yrs.
	24 hrs.	1 yr.
2.00	6 hrs.	50 yrs.
	12 hrs.	25 yrs.
	24 hrs.	5 yrs.
2.50	24 hrs.	10 yrs.

The Water Holding Capacity and Related Properties of Several Soils of Varying Texture (Representative Values) (After Truog)

Class of Soil	Volume Weight	Field Capacity (Hydroscophic and capillary capacity): Percentage by Weight of Oven-dry Soil	Field Capacity: Inches per Acre-foot of Soil	Water Content at Wilting Point: Percentage by Weight of Oven-dry Soil	Water Content at Wilting Point: Inches per Acre-foot of Soil	Water Available to Plants: Percentage by Weight of Oven-dry Soil	Water Available to Plants: Inches per Acre-foot of Soil
Fine Sand	1.6	9	1.9	4	0.9	5	1.0
Sandy Loam	1.4	15	2.5	7	1.2	8	1.3
Silt Loam	1.2	25	3.6	12	1.7	13	1.9
Clay	1.3	30	4.7	16	2.5	14	2.2
Peat	0.4	120	5.8	70	3.4	50	2.4

Each acre-inch of water weighs 113 tons so that the water held in two feet of soil over a single acre weighs from 500 to 1,000 tons. In a region having an annual precipitation of 30 inches, an acre of soil must endure the impact of more than 3,300 tons of water each year and must dispose of that amount by surface retention, infiltration, or runoff, each of which may be followed or accompanied by evaporation and absorption by plants. It is quite evident that the solum* alone constitutes a great reservoir in which precipitation is stored for varying periods of time and from which land plants and animals obtain their supply either directly or indirectly.

KINETIC ENERGY AND NUMBER OF DROPS FOR RAINFALL OF VARIOUS INTENSITIES*

	INTENSITY	MEDIAN DIAMETER	VELOCITY OF FALL	DROPS PER SQ. FT.	KINETIC ENERGY
	Inches per hr.	Millimeters	Ft. per sec.	No.per sec.	Ft.lbs.per sq. ft. per hr.
Fog	0.005	0.01	0.01	6,264,000	4.043×10^8
Mist	.002	.1	.7	2,510	7.937×10^5
Drizzle	.01	.96	13.5	14	.148
Light Rain	.04	1.24	15.7	26	.797
Moderate Rain	.15	1.60	18.7	46	4.241
Heavy Rain	.60	2.05	22.0	46	23.47
Excessive Rain	1.60	2.40	24.0	76	74.48
Cloudburst	4.00	2.85	25.9	113	216.9
Cloudburst	4.00	4.00	29.2	41	275.8
Cloudburst	4.00	6.00	30.5	12	300.7

* Misc. Pub. 768, USDA, 1959

APPENDIX

PART 7

PERCEPTUAL WATER QUALITY STANDARDS

Dale Pfankuch - Hydrologist

PERCEPTUAL WATER QUALITY STANDARDS

Many instrumental techniques have been devised and are currently in use to test various water quality attributes. These tests have the advantage of objective reproducibility, often with great precision. The primary disadvantage is cost. Sampling equipment, collection and transport, and laboratory testing equipment and technicians are expensive. Costs are rising! At the same time costs are rising, the need for more water quality information at more locations is increasing. Is there a way to bridge this widening chasm between data requirements and cost factors? This paper presents one possible solution based on the perceptual ability of Man to subjectively rate his environment.

The subjective rating system which follows is more than a make shift-scheme to be used until the day all of the money and all of the skilled people needed are available. That day very likely will never come. Proposed is a system which will compliment the precise, costly and therefore limited objective testing program of water quality surveillance. It is a system that will utilize the perceptual abilities of the present personnel complement to subjectively gather water quality data on an extensive and routine basis. The public judges the quality of the land and water management on the basis of sensual perception of the specific relative to attitudes formulated over time by instruction and experience. Can we do less than use our good senses in a systematic and directed way to redeem our stewardship responsibilities?

What Our Five Senses Can Tell Us

Sight is perhaps the most useful of the five senses because the stream rater does not have to make physical contact or even be in close proximity to make a value judgment. The closer the observer is, however, the more definitive can be the evaluations. The eye can detect and mind evaluate.

1. The stage and rate of water movement.
2. Color changes and their causes.
3. Aquatic plant and animal life.
4. Foreign deposits in or floating on the water.
5. The components of organic and inorganic materials that make up the channel and bank and the stability of the interactions with the stream.
6. The degree of degradation of one body of water as it merges with another.

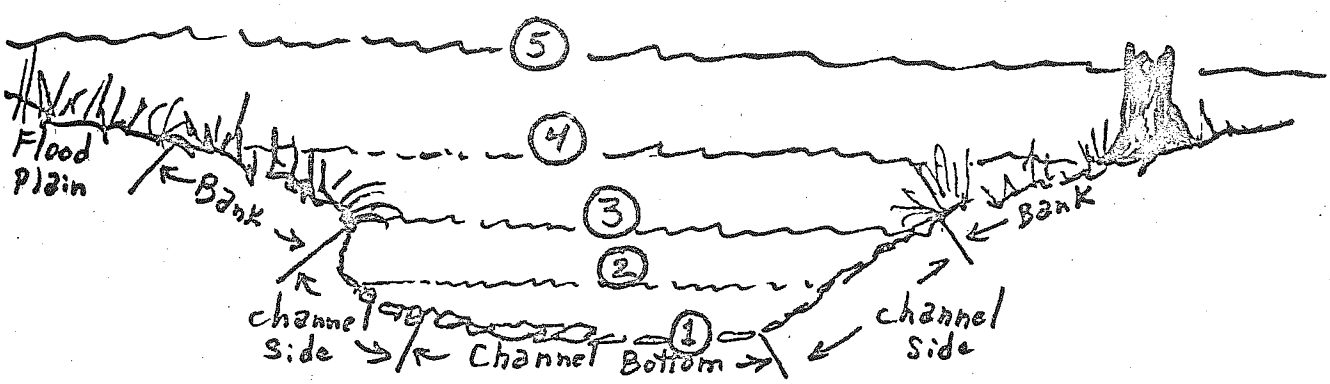
Quality judgments made on the basis of sight alone would generate a great deal of useful information if done systematically to standard criteria on a random and routine basis.

Smell from stagnation or pollution is a useful quality parameter. Compared with sight, the observer must be much closer to detect and identify the cause. Pleasant odors, if unnatural, would be classed as objectionable as well as the offensive smells of natural or man caused origin.

Taste is often tempered by smell. Stimuli from both interact and affect judgment. Since there are few natural streams that are completely safe to drink and because smell influences the quality judgment of taste anyway, the use of this parameter is highly questionable and will not be included in this rating system.

Touch or feel, first of all, reveals relative water temperature. Sensitivity to heat and cold varies widely with individuals but several meaningful classes are described that will provide information which can be related to possible uses. (Thermometers are relatively cheap but they break, get lost or are left behind. This interrupts the record and makes it incomplete for analyses. Besides, it's not compatible with the spirit or intent of this subjective system.) The sense of touch can also be used to confirm or refute the presence of foreign substances which the eye and/or nose inconclusively "detect". Minute quantities of oil, slime, sludge, mineral or organic sediments can be detected in the water or an object in contact with the water. The reaction of the skin to caustic and acid substances is well known. Judgment must, therefore, be exercised at all times to protect against physical and chemical hazards.

Sound alone might have minimal utility in a quality rating scale but used in conjunction with the other senses it has a useful place in the scheme. At least part of the intrigue of Niagara Falls is the noise of the pounding water. Likewise the sound created by fast, turbulent water increases the sense of being a wild and uncontrolled resource. Noise levels are certainly important to both boater and bather alike, because it affects the enjoyment and safety of these contact water sports. Sounds made by a stream can be related to volume and velocity of flow and to the size of channel material that are being moved by saltation and in turn correlated with public enjoyment and safety.



Discharge Stage at the Time of Quality Evaluation

Rating Number	Rating Adjective	Condition Description
0	None	No evaluation made.
1	Dry	Channel sides and bottom exposed to view. Water may be standing in some depressions but there is no surface flow down the channel.
2	Low	Water is flowing, the channel bottom is covered and so are the channel sides in a few places.
3	Full	The channel is full to the edge of the banks.
4	Normal Flood	Water inundates terrestial bank vegetation but follows the normal route of flow.
5	Extreme Flood	Water is out of the normal channel, overtopping the banks and inundating the flood plain.

Visual Turbidity Rating Scale

Rating No.	Rating Adj.	"Drinkability" (if germ free)1/	Still Water 2/ Depth of Object Visibility	Fast Water Color of Spray of Breaking Waves	Recessional Water Marks
1	Clear	Yes	2'+	White	None
2	Slightly Turbid	Maybe	1'-2'	Off-white	None visible to unaided eye.
3	Turbid	Questionable	½'-1'	Noticeably Colored	Visible on smooth surfaces only.
4	Very Turbid	Very Unlikely	¼'-½'	Nearly the same as stream body	Objects coated but identifiable.
5	Muddy	No	0 -¼'	No difference	Objects covered.

1/ Would the rater drink this water if it was known to be germ and odor free and moderate thirst was a factor?

2/ Can light colored objects about 3" in diameter be observed and identified on the bottom.

Temperature Rating Scale

Rating Number	Rating Adjective	Condition Description
1	Frozen	Ice on channel sides and/or bottom. Surface may be frozen over.
2	Cold	No ice but water numbs the extremities in just a few minutes.
3	Cool	A refreshing drink temperature but too cold for most bathers to enjoy for long.
4	Tepid	Too warm for a refreshing drink but just right for prolonged primary water contact.
5	Warm-hot	Bath water temperature and hotter.

Odor Rating Scale

Rating Number	Rating Adjective	Condition Description
1	None	Water "fresh and sweet" No natural or unnatural odors.
2	Hand	Odor is so slight, a sample must be brought close to the nose to detect.
3	Stoop	Odor can't be detected at a distance of more than a few feet from the water on a calm day.
4	Stand	Objectionable odors can be detected without stooping while standing at the waters' edge.
5	Distant	An objectionable odor is evident at a distance from the water.

Sound Rating Scale

Rating Number	Rating Adjective	Condition Description
1	Silent	Little or no water movement--generates no sound.
2	Murmur	Wave action is minimal and sound permits conversations on or near water without raising the voice.
3	Mild	Water turbulence requires voice to be raised to carry on conversation. Water sounds are indistinguishable a few feet back from the shore.
4	Loud	Water very turbulent. Difficult to carry on a conversation near shore or on the water. Voice raised to near a shouting level. Water can be heard up to 50' from the shore.
5	Roar	Water sound violent and can be heard at distances greater than 100 yards. Shouted voices cannot be

APPENDIX

PART 8

FISH SPAWNING TEMPERATURE RANGES

OXYGEN SATURATION GRAPH

Jim Cooper - Fisheries Biologist

If the land manager cannot acquire the services of a fisheries biologist, what then is available to the land manager? Possibly, the scattered data should be brought together, condensed, and summarized for his use. Thus, Figure 1 is an attempt to bring scattered information together (the information in Figure 1 was compiled from over 140 publications) to help the land manager in his management decision.

The material in Figure 1 concerns the water temperature at which fish spawn. Being coldblooded, fish depend on the water temperature regime (seasonal water temperature variations) to function and perpetuate their kind. The water temperature regime helps to regulate growth rates, fish activity, and timing of spawning period.

Since the information in Figure 1 involves ranges (spawning temperature and period), it must be understood that a given species has been known to spawn within the listed ranges. It does not mean that a given species strain has the ability to spawn throughout the temperature or spawning period ranges or that all strains of a species spawn at the same temperature. Also, it should be understood that fewer fish of a given species spawn at the extremes of the temperature ranges. And, a few fish of a species may spawn outside the listed temperature extremes. Thus, any body of water and its related fauna, which will be influenced by land management activities, must still be evaluated on its own characteristics and not lumped into a generalized category.

The most important concept is that the optimum conditions afford the most advantageous opportunity to the species for survival; i.e., if a species spawns under marginal temperature regimes, the species is potentially in a less favorable position than other species existing in the same water under near optimum temperature conditions. For example, a small increase in the average temperature regime of a marginal rainbow trout fishery may result in a temperature regime more favorable to less desirable fish, such as suckers and squawfish, at the expense of the rainbow trout.

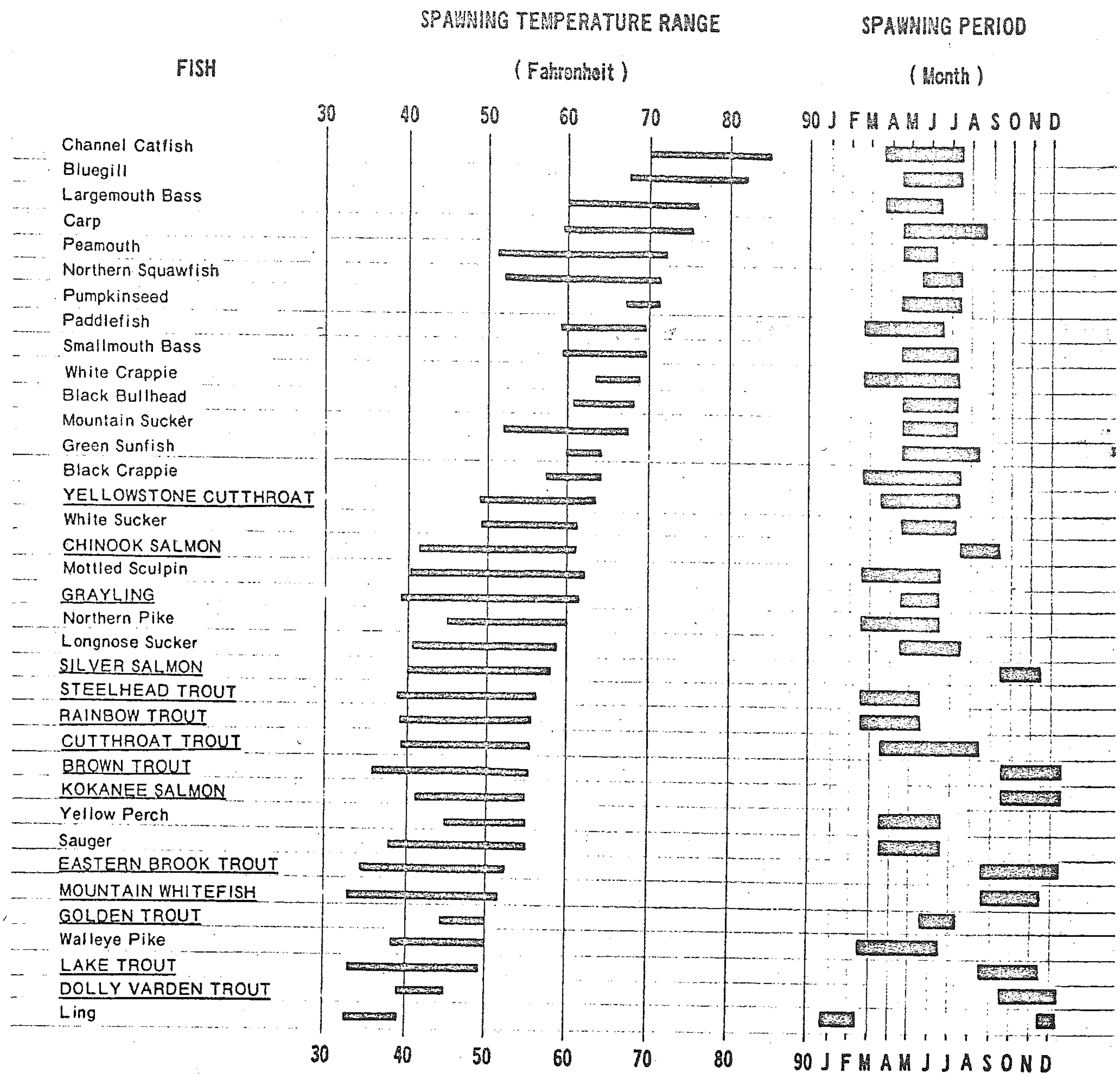


Figure 1.– Water temperature and period during which some fishes spawn in the Northern Region.

APPENDIX

PART 8

WATER RIGHTS

A. What is the "Reservation Doctrine"?

> The Congress and the courts have determined that the United States, through the Forest Service, has a right to reasonable use of water on the National Forests, except those waters appropriated before the National Forests were created.
>
> However, the Forest Service will not exercise this right without full consideration of the rights and uses of others. In addition, such action must be in the public interest.

The legal basis for the Reservation Doctrine is derived from court rulings that reservations of land for public purposes include use of water necessary to the purposes of the reservation. In meeting its public responsibilities, the Forest Service, as every other agency, conforms to laws of the land and decisions of the courts.

<u>History</u>. When the public domain was acquired by the Government of the United States, also acquired was the proprietory right to waters needed for beneficial uses on these lands.

Later, the Desert Land Act of 1877 authorized private parties to obtain, through the States, water rights on the public domain lands not reserved for a particular Federal purpose. The courts have repeatedly ruled that in reserving land from the public domain the United States also reserved and retained the right to the use of water necessary for the purposes of the reservation.

The Reservation Doctrine applies to each National Forest as of the date the National Forest lands were withdrawn and reserved from the public domain. These dates, generally, followed 25 years or more after the Desert Land Act.

Recent court decisions have upheld the Reservation Doctrine, notably a 1963 Supreme Court decision (Arizona vs. California). The Doctrine does not apply to water appropriated through State laws prior to the National Forest land withdrawals, or to lands which have passed from public domain through private ownership before being acquired in the National Forest System.

In some drainages on National Forest lands, water has been completely appropriated under State law <u>after</u> establishment of a National Forest (in other words, after the reservation date). Despite any superior right claimed by the United States, careful evaluation of all water needs will be made before such waters are actually used for National Forest purposes.

B. There is some confusion as to when to file and when not to file on water for National Forest uses. This should clear it up:

FSM 2541.03 - Policy. Water necessary for the development, use and management of resources of the National Forest System will be used in accordance with the reservation principle where applicable. In cases where that principle is applicable, the proper State water agency will be notified of current and foreseeable future National Forest System water requirements ----. Where the principle is not applicable, water rights will be obtained in accordance with State laws. Water rights should be purchased if essential to Forest Service activities and not otherwise available.

Note: Notifications to the States on water use will be made by the R. O. from information provided by the Forests in the water uses and water rights inventory currently underway.

C. When using the reservation principle you should be careful to check the water right records for the stream in question. In many parts of the west, the earliest appropriations precede our reservation dates and often they are filed on the entire streamflow. These prior rights are almost always upheld by the courts on the basis of "first in time - first in right."

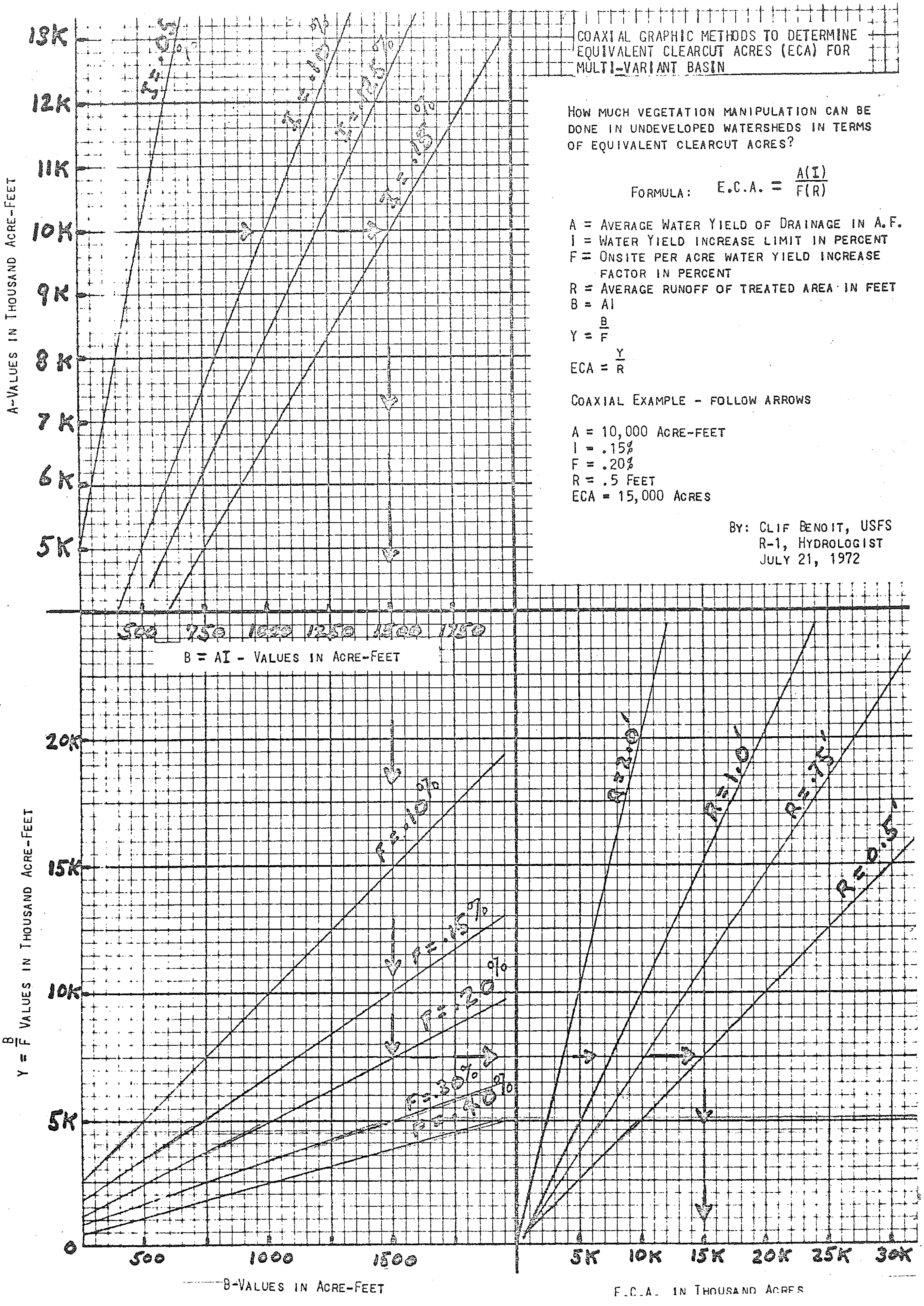
APPENDIX

PART 9

COAXIAL GRAPH FOR E.C.A.

QUANTIFYING SLOPE-EXPOSURE UNITS

WIND CHILL CHART



COAXIAL GRAPHIC METHODS TO DETERMINE EQUIVALENT CLEARCUT ACRES (ECA) FOR MULTI-VARIANT BASIN
HOW MUCH VEGETATION MANIPULATION CAN BE DONE IN UNDEVELOPED WATERSHEDS IN TERMS OF EQUIVALENT CLEARCUT ACRES?
FORMULA: E.C.A. = A(I) / F(R)
A = AVERAGE WATER YIELD OF DRAINAGE IN A.F.
I = WATER YIELD INCREASE LIMIT IN PERCENT
F = ONSITE PER ACRE WATER YIELD INCREASE FACTOR IN PERCENT
R = AVERAGE RUNOFF OF TREATED AREA IN FEET
B = AI
Y = B/F
ECA = Y/R
COAXIAL EXAMPLE - FOLLOW ARROWS
A = 10,000 ACRE-FEET
I = .15%
F = .20%
R = .5 FEET
ECA = 15,000 ACRES
BY: CLIF BENOIT, USFS
R-1, HYDROLOGIST
JULY 21, 1972
A-VALUES IN THOUSAND ACRE-FEET
13K
12K
11K
10K
9K
8K
7K
6K
5K
I=.05%
I=.10%
I=.125%
I=.15%
500
750
1000
1250
1500
1750
B = AI - VALUES IN ACRE-FEET
Y = B/F VALUES IN THOUSAND ACRE-FEET
20K
15K
10K
5K
0
F=.10%
F=.15%
F=.20%
F=.30%
F=.40%
500
1000
1500
B-VALUES IN ACRE-FEET
R=2.0'
R=1.0'
R=.75'
R=0.5'
5K
10K
15K
20K
25K
30K
E.C.A. IN THOUSAND ACRES

A rapid and efficient method of quantifying slope exposure using only a T-square and triangle on a topographic map is described in the "Journal of Hydrology" - 12 (1971) pp. 262-268. The described method accurately defines the boundaries between aspect units, and requires less than one-third the time as the point sampling method.

Briefly, it works like this - Orient a topographic map of any desired scale and contour interval so that the east-west line is aligned along a T-square. Next, identify aspects by sliding a triangle along the T-square and identify the concavity of each contour at the tangent formed by the triangle. See table below.

Tangent	Concavity of Contour	Aspect
Horizontal	Upward	N
Horizontal	Downward	S
Vertical	Upward	E
Vertical	Downward	W
45 - degree	Up-right	NE
45 - degree	Up-left	NW
45 - degree	Down-right	SE
45 - degree	Down-left	SW

Horizontal tangents to contours which are concave upward identify north aspects; concave downward are south aspects. Vertical tangents to contours concave to the right identify east aspects; those concave left are west aspects, etc.

If colors are used for marking and connecting points of tangency, for example, red for horizontal, blue for vertical, and green for 45 - degree tangents, the area is automatically divided into octants of aspect. If only quadrants are desired, the 45 - degree tangents can be omitted.

WIND CHILL CHART

ESTIMATED WIND SPEED IN MPH	ACTUAL THERMOMETER READING (°F.)											
	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
	EQUIVALENT TEMPERATURE (°F.)											
calm	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
5	48	37	27	16	6	-5	-15	-26	-36	-47	-57	-68
10	40	28	16	4	-9	-21	-33	-46	-58	-70	-83	-95
15	36	22	9	-5	-18	-36	-45	-58	-72	-85	-99	-112
20	32	18	4	-10	-25	-39	-53	-67	-82	-96	-110	-124
25	30	16	0	-15	-29	-44	-59	-74	-88	-104	-118	-133
30	28	13	-2	-18	-33	-48	-63	-79	-94	-109	-125	-140
35	27	11	-4	-20	-35	-49	-67	-82	-98	-113	-129	-145
40	26	10	-6	-21	-37	-53	-69	-85	-100	-116	-132	-148

(wind speeds greater than 40 mph have little additional effect)	LITTLE DANGER (for properly clothed person)	INCREASING DANGER	GREAT DANGER
		Danger from freezing of exposed flesh	

APPENDIX

PART 10

HYDROGRAPHIC DATA, TABLES, CONVERSIONS, ETC.

The following selected Data Tables are excerpted from the publication indicated below.

HYDROGRAPHIC DATA BOOK

Seventh Edition

Prepared by

J. C. STEVENS, Dr. Eng.

Mem. Am. Soc. Civil Engineers
Mem. Am. Inst. Electrical Engineers
Mem. Am. Inst. Consulting Engineers

Published by

LEUPOLD & STEVENS INSTRUMENTS, INC.

P. O. Box 25347
PORTLAND, OREGON, U.S.A 97225

TABLE 6

DECIMALS OF A FOOT

FOR EACH 1/16 OF AN INCH FROM 1/16 TO 12 INCHES

Fraction	Decimal	Fraction	Decimal	Fraction	Decimal	Fraction	Decimal
1/16	0.0052	3 1/16	0.2552	6 1/16	0.5052	9 1/16	0.7552
1/8	0.0104	3 1/8	0.2604	6 1/8	0.5104	9 1/8	0.7604
3/16	0.0156	3 3/16	0.2656	6 3/16	0.5156	9 3/16	0.7656
1/4	0.0208	3 1/4	0.2708	6 1/4	0.5208	9 1/4	0.7708
5/16	0.0260	3 5/16	0.2760	6 5/16	0.5260	9 5/16	0.7760
3/8	0.0313	3 3/8	0.2813	6 3/8	0.5313	9 3/8	0.7813
7/16	0.0365	3 7/16	0.2865	6 7/16	0.5365	9 7/16	0.7865
1/2	0.0417	3 1/2	0.2917	6 1/2	0.5417	9 1/2	0.7917
9/16	0.0469	3 9/16	0.2969	6 9/16	0.5469	9 9/16	0.7969
5/8	0.0521	3 5/8	0.3021	6 5/8	0.5521	9 5/8	0.8021
11/16	0.0573	3 11/16	0.3073	6 11/16	0.5573	9 11/16	0.8073
3/4	0.0625	3 3/4	0.3125	6 3/4	0.5625	9 3/4	0.8125
13/16	0.0677	3 13/16	0.3177	6 13/16	0.5677	9 13/16	0.8177
7/8	0.0729	3 7/8	0.3229	6 7/8	0.5729	9 7/8	0.8229
15/16	0.0781	3 15/16	0.3281	6 15/16	0.5781	9 15/16	0.8281
1	0.0833	4	0.3333	7	0.5833	10	0.8333
1 1/16	0.0885	4 1/16	0.3385	7 1/16	0.5885	10 1/16	0.8385
1 1/8	0.0938	4 1/8	0.3438	7 1/8	0.5938	10 1/8	0.8438
1 3/16	0.0990	4 3/16	0.3490	7 3/16	0.5990	10 3/16	0.8490
1 1/4	0.1042	4 1/4	0.3542	7 1/4	0.6042	10 1/4	0.8542
1 5/16	0.1094	4 5/16	0.3594	7 5/16	0.6094	10 5/16	0.8594
1 3/8	0.1146	4 3/8	0.3646	7 3/8	0.6146	10 3/8	0.8646
1 7/16	0.1198	4 7/16	0.3698	7 7/16	0.6198	10 7/16	0.8698
1 1/2	0.1250	4 1/2	0.3750	7 1/2	0.6250	10 1/2	0.8750
1 9/16	0.1302	4 9/16	0.3802	7 9/16	0.6302	10 9/16	0.8802
1 5/8	0.1354	4 5/8	0.3854	7 5/8	0.6354	10 5/8	0.8854
1 11/16	0.1406	4 11/16	0.3906	7 11/16	0.6406	10 11/16	0.8906
1 3/4	0.1458	4 3/4	0.3958	7 3/4	0.6458	10 3/4	0.8958
1 13/16	0.1510	4 13/16	0.4010	7 13/16	0.6510	10 13/16	0.9010
1 7/8	0.1563	4 7/8	0.4063	7 7/8	0.6563	10 7/8	0.9063
1 15/16	0.1615	4 15/16	0.4115	7 15/16	0.6615	10 15/16	0.9115
2	0.1667	5	0.4167	8	0.6667	11	0.9167
2 1/16	0.1719	5 1/16	0.4219	8 1/16	0.6719	11 1/16	0.9219
2 1/8	0.1771	5 1/8	0.4271	8 1/8	0.6771	11 1/8	0.9271
2 3/16	0.1823	5 3/16	0.4323	8 3/16	0.6823	11 3/16	0.9323
2 1/4	0.1875	5 1/4	0.4375	8 1/4	0.6875	11 1/4	0.9375
2 5/16	0.1927	5 5/16	0.4427	8 5/16	0.6927	11 5/16	0.9427
2 3/8	0.1979	5 3/8	0.4479	8 3/8	0.6979	11 3/8	0.9479
2 7/16	0.2031	5 7/16	0.4531	8 7/16	0.7031	11 7/16	0.9531
2 1/2	0.2083	5 1/2	0.4583	8 1/2	0.7083	11 1/2	0.9583
2 9/16	0.2135	5 9/16	0.4635	8 9/16	0.7135	11 9/16	0.9635
2 5/8	0.2188	5 5/8	0.4688	8 5/8	0.7188	11 5/8	0.9688
2 11/16	0.2240	5 11/16	0.4740	8 11/16	0.7240	11 11/16	0.9740
2 3/4	0.2292	5 3/4	0.4792	8 3/4	0.7292	11 3/4	0.9792
2 13/16	0.2344	5 13/16	0.4844	8 13/16	0.7344	11 13/16	0.9844
2 7/8	0.2396	5 7/8	0.4896	8 7/8	0.7396	11 7/8	0.9896
2 15/16	0.2448	5 15/16	0.4948	8 15/16	0.7448	11 15/16	0.9948
3	0.2500	6	0.5000	9	0.7500	12	1.0000

TABLE 7
AREAS OF CIRCLES BY HUNDREDTHS

Diam.	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	0.000	0.000	0.000	0.001	0.001	0.002	0.003	0.004	0.005	0.006
0.1	0.008	0.010	0.011	0.013	0.015	0.018	0.020	0.023	0.025	0.028
0.2	0.031	0.035	0.038	0.042	0.045	0.049	0.053	0.057	0.062	0.066
0.3	0.071	0.075	0.080	0.086	0.091	0.096	0.102	0.108	0.113	0.119
0.4	0.126	0.132	0.139	0.145	0.152	0.159	0.166	0.173	0.181	0.189
0.5	0.196	0.204	0.212	0.221	0.229	0.238	0.246	0.255	0.264	0.273
0.6	0.283	0.292	0.302	0.312	0.322	0.332	0.342	0.353	0.363	0.374
0.7	0.385	0.396	0.407	0.419	0.430	0.442	0.454	0.466	0.478	0.490
0.8	0.503	0.515	0.528	0.541	0.554	0.567	0.581	0.594	0.608	0.622
0.9	0.636	0.650	0.665	0.679	0.694	0.709	0.724	0.739	0.754	0.770
1.0	0.785	0.801	0.817	0.833	0.849	0.866	0.882	0.899	0.916	0.933
1.1	0.950	0.968	0.985	1.003	1.021	1.039	1.057	1.075	1.094	1.112
1.2	1.131	1.150	1.169	1.188	1.208	1.227	1.247	1.267	1.287	1.307
1.3	1.327	1.348	1.368	1.389	1.410	1.431	1.453	1.474	1.496	1.517
1.4	1.539	1.561	1.584	1.606	1.629	1.651	1.674	1.697	1.720	1.744
1.5	1.767	1.791	1.815	1.839	1.863	1.887	1.911	1.936	1.961	1.986
1.6	2.011	2.036	2.061	2.087	2.112	2.138	2.164	2.190	2.217	2.243
1.7	2.270	2.297	2.324	2.351	2.378	2.405	2.433	2.461	2.488	2.516
1.8	2.545	2.573	2.602	2.630	2.659	2.688	2.717	2.746	2.776	2.806
1.9	2.835	2.865	2.895	2.926	2.956	2.986	3.017	3.048	3.079	3.110
2.0	3.142	3.173	3.205	3.237	3.269	3.301	3.333	3.365	3.398	3.431
2.1	3.464	3.497	3.530	3.563	3.597	3.631	3.664	3.698	3.733	3.767
2.2	3.801	3.836	3.871	3.906	3.941	3.976	4.011	4.047	4.083	4.119
2.3	4.155	4.191	4.227	4.264	4.301	4.337	4.374	4.412	4.449	4.486
2.4	4.524	4.562	4.600	4.638	4.676	4.714	4.753	4.792	4.831	4.870
2.5	4.909	4.948	4.988	5.027	5.067	5.107	5.147	5.187	5.228	5.269
2.6	5.309	5.350	5.391	5.433	5.474	5.515	5.557	5.599	5.641	5.683
2.7	5.726	5.768	5.811	5.853	5.896	5.940	5.983	6.026	6.070	6.114
2.8	6.158	6.202	6.246	6.290	6.335	6.379	6.424	6.469	6.514	6.560
2.9	6.605	6.651	6.697	6.743	6.789	6.835	6.881	6.928	6.975	7.022
3.0	7.069	7.116	7.163	7.211	7.258	7.306	7.354	7.402	7.451	7.499
3.1	7.548	7.596	7.645	7.694	7.744	7.793	7.843	7.892	7.942	7.992
3.2	8.042	8.093	8.143	8.194	8.245	8.296	8.347	8.398	8.450	8.501
3.3	8.553	8.605	8.657	8.709	8.762	8.814	8.867	8.920	8.973	9.026
3.4	9.079	9.133	9.186	9.240	9.294	9.348	9.402	9.457	9.511	9.566
3.5	9.62	9.68	9.73	9.79	9.84	9.90	9.95	10.01	10.07	10.12
3.6	10.18	10.24	10.29	10.35	10.41	10.46	10.52	10.58	10.64	10.69
3.7	10.75	10.81	10.87	10.93	10.99	11.04	11.10	11.16	11.22	11.28
3.8	11.34	11.40	11.46	11.52	11.58	11.64	11.70	11.76	11.82	11.88
3.9	11.95	12.01	12.07	12.13	12.19	12.25	12.32	12.38	12.44	12.50
4.0	12.57	12.63	12.69	12.76	12.82	12.88	12.95	13.01	13.07	13.14
4.1	13.20	13.27	13.33	13.40	13.46	13.53	13.59	13.66	13.72	13.79
4.2	13.85	13.92	13.99	14.05	14.12	14.19	14.25	14.32	14.39	14.45
4.3	14.52	14.59	14.66	14.73	14.79	14.86	14.93	15.00	15.07	15.14
4.4	15.21	15.27	15.34	15.41	15.48	15.55	15.62	15.69	15.76	15.83
4.5	15.90	15.98	16.05	16.12	16.19	16.26	16.33	16.40	16.47	16.55
4.6	16.62	16.69	16.76	16.84	16.91	16.98	17.06	17.13	17.20	17.28
4.7	17.35	17.42	17.50	17.57	17.65	17.72	17.80	17.87	17.95	18.02
4.8	18.10	18.17	18.25	18.32	18.40	18.47	18.55	18.63	18.70	18.78
	18.8	[illegible]	19.0	9	19.	24	19	40	19	.56

TABLE 7 — Continued

Diam.	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
5.0	19.63	19.71	19.79	19.87	19.95	20.03	20.11	20.19	20.27	20.35
.1	20.43	20.51	20.59	20.67	20.75	20.83	20.91	20.99	21.07	21.16
.2	21.24	21.32	21.40	21.48	21.57	21.65	21.73	21.81	21.90	21.98
.3	22.06	22.15	22.23	22.31	22.40	22.48	22.56	22.65	22.73	22.82
.4	22.90	22.99	23.07	23.16	23.24	23.33	23.41	23.50	23.59	23.67
5.5	23.76	23.84	23.93	24.02	24.11	24.19	24.28	24.37	24.45	24.54
.6	24.63	24.72	24.81	24.89	24.98	25.07	25.16	25.25	25.34	25.43
.7	25.52	25.61	25.70	25.79	25.88	25.97	26.06	26.15	26.24	26.33
.8	26.42	26.51	26.60	26.69	26.79	26.88	26.97	27.06	27.15	27.25
.9	27.34	27.43	27.53	27.62	27.71	27.81	27.90	27.99	28.09	28.18
6.0	28.27	28.37	28.46	28.56	28.65	28.75	28.84	28.94	29.03	29.13
.1	29.22	29.32	29.42	29.51	29.61	29.71	29.80	29.90	30.00	30.09
.2	30.19	30.29	30.39	30.48	30.58	30.68	30.78	30.88	30.97	31.07
.3	31.17	31.27	31.37	31.47	31.57	31.67	31.77	31.87	31.97	32.07
.4	32.17	32.27	32.37	32.47	32.57	32.67	32.78	32.88	32.98	33.08
6.5	33.18	33.29	33.39	33.49	33.59	33.70	33.80	33.90	34.00	34.11
.6	34.21	34.32	34.42	34.52	34.63	34.73	34.84	34.94	35.05	35.15
.7	35.26	35.36	35.47	35.57	35.68	35.78	35.89	36.00	36.10	36.21
.8	36.32	36.42	36.53	36.64	36.75	36.85	36.96	37.07	37.18	37.28
.9	37.39	37.50	37.61	37.72	37.83	37.94	38.05	38.16	38.26	38.37
7.0	38.48	38.59	38.70	38.82	38.93	39.04	39.15	39.26	39.37	39.48
.1	39.59	39.70	39.82	39.93	40.04	40.15	40.26	40.38	40.49	40.60
.2	40.72	40.83	40.94	41.06	41.17	41.28	41.40	41.51	41.62	41.74
.3	41.85	41.97	42.08	42.20	42.31	42.43	42.54	42.66	42.78	42.89
.4	43.01	43.12	43.24	43.36	43.47	43.59	43.71	43.83	43.94	44.06
7.5	44.18	44.30	44.41	44.53	44.65	44.77	44.89	45.01	45.13	45.25
.6	45.36	45.48	45.60	45.72	45.84	45.96	46.08	46.20	46.32	46.45
.7	46.57	46.69	46.81	46.93	47.05	47.17	47.29	47.42	47.54	47.66
.8	47.78	47.91	48.03	48.15	48.27	48.40	48.52	48.65	48.77	48.89
.9	49.02	49.14	49.27	49.39	49.51	49.64	49.76	49.89	50.01	50.14
8.0	50.27	50.39	50.52	50.64	50.77	50.90	51.02	51.15	51.28	51.40
.1	51.53	51.66	51.78	51.91	52.04	52.17	52.30	52.42	52.55	52.68
.2	52.81	52.94	53.07	53.20	53.33	53.46	53.59	53.72	53.85	53.98
.3	54.11	54.24	54.37	54.50	54.63	54.76	54.89	55.02	55.15	55.29
.4	55.42	55.55	55.68	55.81	55.95	56.08	56.21	56.35	56.48	56.61
8.5	56.75	56.88	57.01	57.15	57.28	57.41	57.55	57.68	57.82	57.95
.6	58.09	58.22	58.36	58.49	58.63	58.77	58.90	59.04	59.17	59.31
.7	59.45	59.58	59.72	59.86	59.99	60.13	60.27	60.41	60.55	60.68
.8	60.82	60.96	61.10	61.24	61.38	61.51	61.65	61.79	61.93	62.07
.9	62.21	62.35	62.49	62.63	62.77	62.91	63.05	63.19	63.33	63.48
9.0	63.62	63.76	63.90	64.04	64.18	64.33	64.47	64.61	64.75	64.90
.1	65.04	65.18	65.33	65.47	65.61	65.76	65.90	66.04	66.19	66.33
.2	66.48	66.62	66.77	66.91	67.06	67.20	67.35	67.49	67.64	67.78
.3	67.93	68.08	68.22	68.37	68.51	68.66	68.81	68.96	69.10	69.25
.4	69.40	69.55	69.69	69.84	69.99	70.14	70.29	70.44	70.58	70.73
9.5	70.88	71.03	71.18	71.33	71.48	71.63	71.78	71.93	72.08	72.23
.6	72.38	72.53	72.68	72.84	72.99	73.14	73.29	73.44	73.59	73.75
.7	73.90	74.05	74.20	74.36	74.51	74.66	74.82	74.97	75.12	75.28
.8	75.43	75.58	75.74	75.89	76.05	76.20	76.36	76.51	76.67	76.82
.9	76.98	77.13	77.29	77.44	77.60	77.76	77.91	78.07	78.23	78.38

TABLE 7 — Continued

Diam.	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
10.0	78.54	78.70	78.85	79.01	79.17	79.33	79.49	79.64	79.80	79.96
10.1	80.12	80.28	80.44	80.60	80.75	80.91	81.07	81.23	81.39	81.55
10.2	81.71	81.87	82.03	82.19	82.35	82.52	82.68	82.84	83.00	83.16
10.3	83.32	83.48	83.65	83.81	83.97	84.13	84.30	84.46	84.62	84.79
10.4	84.95	85.11	85.28	85.44	85.60	85.77	85.93	86.10	86.26	86.43
10.5	86.59	86.76	86.92	87.09	87.25	87.42	87.58	87.75	87.91	88.08
10.6	88.25	88.41	88.58	88.75	88.91	89.08	89.25	89.42	89.58	89.75
10.7	89.92	90.09	90.26	90.43	90.59	90.76	90.93	91.10	91.27	91.44
10.8	91.61	91.78	91.95	92.12	92.29	92.46	92.63	92.80	92.97	93.14
10.9	93.31	93.48	93.66	93.83	94.00	94.17	94.34	94.52	94.69	94.86
11.0	95.03	95.21	95.38	95.55	95.73	95.90	96.07	96.25	96.42	96.59
11.1	96.77	96.94	97.12	97.29	97.47	97.64	97.82	97.99	98.17	98.34
11.2	98.52	98.70	98.87	99.05	99.23	99.40	99.58	99.76	99.93	100.11
11.3	100.29	100.46	100.64	100.82	101.00	101.18	101.36	101.53	101.71	101.89
11.4	102.07	102.25	102.43	102.61	102.79	102.97	103.15	103.33	103.51	103.69
11.5	103.87	104.05	104.23	104.41	104.59	104.77	104.96	105.14	105.32	105.50
11.6	105.68	105.87	106.05	106.23	106.41	106.60	106.78	106.96	107.15	107.33
11.7	107.51	107.70	107.88	108.07	108.25	108.43	108.62	108.80	108.99	109.17
11.8	109.36	109.54	109.73	109.92	110.10	110.29	110.47	110.66	110.85	111.03
11.9	111.22	111.41	111.59	111.78	111.97	112.16	112.34	112.53	112.72	112.91
12.0	113.10	113.29	113.47	113.66	113.85	114.04	114.23	114.42	114.61	114.80
12.1	114.99	115.18	115.37	115.56	115.75	115.94	116.13	116.32	116.52	116.71
12.2	116.90	117.09	117.28	117.47	117.67	117.86	118.05	118.24	118.44	118.63
12.3	118.82	119.02	119.21	119.40	119.60	119.79	119.98	120.18	120.37	120.57
12.4	120.76	120.96	121.15	121.35	121.54	121.74	121.93	122.13	122.33	122.52
12.5	122.72	122.91	123.11	123.31	123.51	123.70	123.90	124.10	124.29	124.49
12.6	124.69	124.89	125.09	125.28	125.48	125.68	125.88	126.08	126.28	126.48
12.7	126.68	126.88	127.08	127.28	127.48	127.68	127.88	128.08	128.28	128.48
12.8	128.68	128.88	129.08	129.28	129.49	129.69	129.89	130.09	130.29	130.50
12.9	130.70	130.90	131.10	131.31	131.51	131.71	131.92	132.12	132.32	132.53
13.0	132.73	132.94	133.14	133.35	133.55	133.76	133.96	134.17	134.37	134.58
13.1	134.78	134.99	135.19	135.40	135.61	135.81	136.02	136.23	136.43	136.64
13.2	136.85	137.06	137.26	137.47	137.68	137.89	138.09	138.30	138.51	138.72
13.3	138.93	139.14	139.35	139.56	139.77	139.98	140.19	140.40	140.61	140.82
13.4	141.03	141.24	141.45	141.66	141.87	142.08	142.29	142.50	142.72	142.93
13.5	143.14	143.35	143.56	143.78	143.99	144.20	144.41	144.63	144.84	145.05
13.6	145.27	145.48	145.69	145.91	146.12	146.34	146.55	146.77	146.98	147.20
13.7	147.41	147.63	147.84	148.06	148.27	148.49	148.71	148.92	149.14	149.35
13.8	149.57	149.79	150.01	150.22	150.44	150.66	150.87	151.09	151.31	151.53
13.9	151.75	151.97	152.18	152.40	152.62	152.84	153.06	153.28	153.50	153.72
14.0	153.94	154.16	154.38	154.60	154.82	155.04	155.26	155.48	155.70	155.92
14.1	156.14	156.37	156.59	156.81	157.03	157.25	157.48	157.70	157.92	158.14
14.2	158.37	158.59	158.81	159.04	159.26	159.48	159.71	159.93	160.16	160.38
14.3	160.61	160.83	161.06	161.28	161.51	161.73	161.96	162.18	162.41	162.63
14.4	162.86	163.09	163.31	163.54	163.77	163.99	164.22	164.45	164.67	164.90
14.5	165.13	165.36	165.59	165.81	166.04	166.27	166.50	166.73	166.96	167.19
14.6	167.42	167.65	167.88	168.11	168.34	168.57	168.80	169.03	169.26	169.49
14.7	169.72	169.95	170.18	170.41	170.64	170.87	171.10	171.34	171.57	171.80
14.8	172.03	172.27	172.50	172.73	172.96	173.20	173.43	173.66	173.90	174.13
14.9	174.37	174.60	174.83	175.07	175.30	175.54	175.77	176.01	176.24	176.48

TABLE 7 — Continued

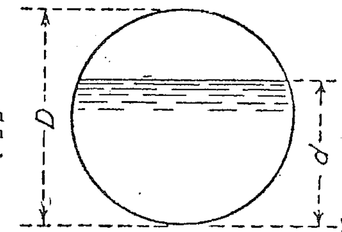
Diam.	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
15.0	176.71	176.95	177.19	177.42	177.66	177.89	178.13	178.37	178.60	178.84
15.1	179.08	179.32	179.55	179.79	180.03	180.27	180.50	180.74	180.98	181.22
15.2	181.46	181.70	181.94	182.18	182.41	182.65	182.89	183.13	183.37	183.61
15.3	183.85	184.09	184.33	184.58	184.82	185.06	185.30	185.54	185.78	186.02
15.4	186.27	186.51	186.75	186.99	187.23	187.48	187.72	187.96	188.21	188.45
15.5	188.69	188.94	189.18	189.42	189.67	189.91	190.16	190.40	190.64	190.89
15.6	191.13	191.38	191.62	191.87	192.12	192.36	192.61	192.85	193.10	193.35
15.7	193.59	193.84	194.09	194.33	194.58	194.83	195.08	195.32	195.57	195.82
15.8	196.07	196.32	196.56	196.81	197.06	197.31	197.56	197.81	198.06	198.31
15.9	198.56	198.81	199.06	199.31	199.56	199.81	200.06	200.31	200.56	200.81
16.0	201.06	201.31	201.56	201.82	202.07	202.32	202.57	202.83	203.08	203.33
16.1	203.58	203.84	204.09	204.34	204.60	204.85	205.10	205.36	205.61	205.87
16.2	206.12	206.37	206.63	206.88	207.14	207.39	207.65	207.91	208.16	208.42
16.3	208.67	208.93	209.18	209.44	209.70	209.95	210.21	210.47	210.73	210.98
16.4	211.24	211.50	211.76	212.01	212.27	212.53	212.79	213.05	213.31	213.57
16.5	213.82	214.08	214.34	214.60	214.86	215.12	215.38	215.64	215.90	216.16
16.6	216.42	216.69	216.95	217.21	217.47	217.73	217.99	218.25	218.52	218.78
16.7	219.04	219.30	219.56	219.83	220.09	220.35	220.62	220.88	221.14	221.41
16.8	221.67	221.93	222.20	222.46	222.73	222.99	223.26	223.52	223.79	224.05
16.9	224.32	224.58	224.85	225.11	225.38	225.65	225.91	226.18	226.45	226.71
17.0	226.98	227.25	227.51	227.78	228.05	228.32	228.59	228.85	229.12	229.39
17.1	229.66	229.93	230.20	230.46	230.73	231.00	231.27	231.54	231.81	232.08
17.2	232.35	232.62	232.89	233.16	233.43	233.71	233.98	234.25	234.52	234.79
17.3	235.06	235.33	235.61	235.88	236.15	236.42	236.70	236.97	237.24	237.51
17.4	237.79	238.06	238.33	238.61	238.88	239.16	239.43	239.70	239.98	240.25
17.5	240.53	240.80	241.08	241.35	241.63	241.90	242.18	242.46	242.73	243.01
17.6	243.28	243.56	243.84	244.12	244.39	244.67	244.95	245.22	245.50	245.78
17.7	246.06	246.34	246.61	246.89	247.17	247.45	247.73	248.01	248.29	248.57
17.8	248.85	249.13	249.41	249.69	249.97	250.25	250.53	250.81	251.09	251.37
17.9	251.65	251.93	252.21	252.49	252.78	253.06	253.34	253.62	253.90	254.19
18.0	254.47	254.75	255.03	255.32	255.60	255.88	256.17	256.45	256.74	257.02
18.1	257.30	257.59	257.87	258.16	258.44	258.73	259.01	259.30	259.58	259.87
18.2	260.16	260.44	260.73	261.01	261.30	261.59	261.87	262.16	262.45	262.73
18.3	263.02	263.31	263.60	263.89	264.17	264.46	264.75	265.04	265.33	265.62
18.4	265.90	266.19	266.48	266.77	267.06	267.35	267.64	267.93	268.22	268.51
18.5	268.80	269.09	269.38	269.68	269.97	270.26	270.55	270.84	271.13	271.42
18.6	271.72	272.01	272.30	272.59	272.89	273.18	273.47	273.77	274.06	274.35
18.7	274.65	274.94	275.23	275.53	275.82	276.12	276.41	276.71	277.00	277.30
18.8	277.59	277.89	278.18	278.48	278.77	279.07	279.37	279.66	279.96	280.26
18.9	280.55	280.85	281.15	281.44	281.74	282.04	282.34	282.63	282.93	283.23
19.0	283.53	283.83	284.13	284.42	284.72	285.02	285.32	285.62	285.92	286.22
19.1	286.52	286.82	287.12	287.42	287.72	288.02	288.32	288.63	288.93	289.23
19.2	289.53	289.83	290.13	290.43	290.74	291.04	291.34	291.64	291.95	292.25
19.3	292.55	292.86	293.16	293.46	293.77	294.07	294.37	294.68	294.98	295.29
19.4	295.59	295.90	296.20	296.51	296.81	297.12	297.42	297.73	298.04	298.34
19.5	298.65	298.95	299.26	299.57	299.87	300.18	300.49	300.80	301.10	301.41
19.6	301.72	302.03	302.33	302.64	302.95	303.26	303.57	303.88	304.19	304.50
19.7	304.81	305.11	305.42	305.73	306.04	306.35	306.66	306.98	307.29	307.60
19.8	307.91	308.22	308.53	308.84	309.15	309.46	309.78	310.09	310.40	310.71
19.9	311.03	311.34	311.65	311.96	312.28	312.59	312.90	313.22	313.53	313.85

TABLE 8
SEGMENTS OF CIRCLES

d/D	area/D²	wet. per./D	hyd. rad./D	d/D	area/D²	wet. per./D	hyd. rad./D
[illegible]	0.0013	0.2003	0.0066	0.51	0.4027	1.5908	0.2531
[illegible]	0.0037	0.2838	0.0132	0.52	0.4127	1.6108	0.2561
[illegible]	0.0069	0.3482	0.0197	0.53	0.4227	1.6308	0.2591
[illegible]	0.0105	0.4027	0.0262	0.54	0.4327	1.6509	0.2620
[illegible]	0.0147	0.4510	0.0326	0.55	0.4426	1.6710	0.2649
[illegible]	0.0192	0.4949	0.0389	0.56	0.4526	1.6911	0.2676
[illegible]	0.0242	0.5355	0.0451	0.57	0.4625	1.7113	0.2703
[illegible]	0.0294	0.5735	0.0513	0.58	0.4723	1.7315	0.2728
[illegible]	0.0350	0.6094	0.0574	0.59	0.4822	1.7518	0.2753
[illegible]	0.0409	0.6435	0.0635	0.60	0.4920	1.7722	0.2776
[illegible]	0.0470	0.6761	0.0695	0.61	0.5018	1.7926	0.2797
[illegible]	0.0534	0.7075	0.0754	0.62	0.5115	1.8132	0.2818
[illegible]	0.0600	0.7377	0.0813	0.63	0.5212	1.8338	0.2839
[illegible]	0.0668	0.7670	0.0871	0.64	0.5308	1.8546	0.2860
[illegible]	0.0739	0.7954	0.0929	0.65	0.5404	1.8755	0.2881
[illegible]	0.0811	0.8230	0.0986	0.66	0.5499	1.8965	0.2899
[illegible]	0.0885	0.8500	0.1042	0.67	0.5594	1.9177	0.2917
[illegible]	0.0961	0.8763	0.1097	0.68	0.5687	1.9391	0.2935
[illegible]	0.1039	0.9020	0.1152	0.69	0.5780	1.9606	0.2950
[illegible]	0.1118	0.9273	0.1206	0.70	0.5872	1.9823	0.2962
[illegible]	0.1199	0.9521	0.1259	0.71	0.5964	2.0042	0.2973
[illegible]	0.1281	0.9764	0.1312	0.72	0.6054	2.0264	0.2984
[illegible]	0.1365	1.0003	0.1364	0.73	0.6143	2.0488	0.2995
[illegible]	0.1449	1.0239	0.1416	0.74	0.6231	2.0714	0.3006
[illegible]	0.1535	1.0472	0.1466	0.75	0.6318	2.0944	0.3017
[illegible]	0.1623	1.0701	0.1516	0.76	0.6404	2.1176	0.3025
[illegible]	0.1711	1.0928	0.1566	0.77	0.6489	2.1412	0.3032
[illegible]	0.1800	1.1152	0.1614	0.78	0.6573	2.1652	0.3037
[illegible]	0.1890	1.1373	0.1662	0.79	0.6655	2.1895	0.3040
[illegible]	0.1982	1.1593	0.1709	0.80	0.6736	2.2143	0.3042
[illegible]	0.2074	1.1810	0.1755	0.81	0.6815	2.2395	0.3044
[illegible]	0.2167	1.2025	0.1801	0.82	0.6893	2.2653	0.3043
[illegible]	0.2260	1.2239	0.1848	0.83	0.6969	2.2916	0.3041
[illegible]	0.2355	1.2451	0.1891	0.84	0.7043	2.3186	0.3038
[illegible]	0.2450	1.2661	0.1935	0.85	0.7115	2.3462	0.3033
[illegible]	0.2546	1.2870	0.1978	0.86	0.7186	2.3746	0.3026
[illegible]	0.2642	1.3078	0.2020	0.87	0.7254	2.4038	0.3017
[illegible]	0.2739	1.3284	0.2061	0.88	0.7320	2.4341	0.3008
[illegible]	0.2836	1.3490	0.2102	0.89	0.7384	2.4655	0.2996
[illegible]	0.2934	1.3694	0.2142	0.90	0.7445	2.4981	0.2980
[illegible]	0.3032	1.3898	0.2181	0.91	0.7504	2.5322	0.2963
[illegible]	0.3130	1.4101	0.2220	0.92	0.7560	2.5681	0.2944
[illegible]	0.3229	1.4303	0.2257	0.93	0.7612	2.6061	0.2922
[illegible]	0.3328	1.4505	0.2294	0.94	0.7662	2.6467	0.2896
[illegible]	0.3428	1.4706	0.2331	0.95	0.7707	2.6906	0.2864
[illegible]	0.3527	1.4907	0.2366	0.96	0.7749	2.7389	0.2830
[illegible]	0.3627	1.5108	0.2400	0.97	0.7785	2.7934	0.2787
[illegible]	0.3727	1.5308	0.2434	0.98	0.7816	2.8578	0.2735
[illegible]	0.3827	1.5508	0.2467	0.99	0.7841	2.9412	0.2665
[illegible]	0.3927	1.5708	0.2500	1.00	0.7854	3.1416	0.2500

TABLE 10
CIRCULAR CONDUITS PARTLY FULL

D= Diameter of circle.
d= Depth of water.
hv= Velocity head for a critical depth of d.
Q= Discharge when the critical depth is d.
P= Pressure on cross section of water prism in cubic units of water. To get P in pounds, when d and D are in feet, multiply by 62.5.



$\frac{d}{D}$	$\frac{hv}{D}$	$\frac{Q}{D^{5/2}}$	$\frac{P}{D^3}$	$\frac{d}{D}$	$\frac{hv}{D}$	$\frac{Q}{D^{5/2}}$	$\frac{P}{D^3}$	$\frac{d}{D}$	$\frac{hv}{D}$	$\frac{Q}{D^{5/2}}$	$\frac{P}{D^3}$
1	2	3	4	1	2	3	4	1	2	3	4
.01	.0033	.0006	.0000	.34	.1243	.6657	.0332	.67	.2974	2.4464	.1644
.02	.0067	.0025	.0000	.35	.1284	.7040	.0356	.68	.3048	2.5182	.1700
.03	.0101	.0055	.0001	.36	.1326	.7433	.0381	.69	.3125	2.5912	.1758
.04	.0134	.0098	.0002	.37	.1368	.7836	.0407	.70	.3204	2.6656	.1816
.05	.0168	.0153	.0003	.38	.1411	.8249	.0434	.71	.3286	2.7414	.1875
.06	.0203	.0220	.0005	.39	.1454	.8671	.0462	.72	.3371	2.8188	.1935
.07	.0237	.0298	.0007	.40	.1497	.9103	.0491	.73	.3459	2.8977	.1996
.08	.0271	.0389	.0010	.41	.1541	.9545	.0520	.74	.3552	2.9783	.2058
.09	.0306	.0491	.0013	.42	.1586	.9996	.0551	.75	.3648	3.0607	.2121
.10	.0341	.0605	.0017	.43	.1631	1.0458	.0583	.76	.3749	3.1450	.2185
.11	.0376	.0731	.0021	.44	.1676	1.0929	.0616	.77	.3855	3.2314	.2249
.12	.0411	.0868	.0026	.45	.1723	1.1410	.0650	.78	.3967	3.3200	.2314
.13	.0446	.1016	.0032	.46	.1769	1.1899	.0684	.79	.4085	3.4112	.2380
.14	.0482	.1176	.0038	.47	.1817	1.2399	.0720	.80	.4210	3.5050	.2447
.15	.0517	.1347	.0045	.48	.1865	1.2908	.0757	.81	.4343	3.6019	.2515
.16	.0553	.1530	.0053	.49	.1914	1.3427	.0795	.82	.4485	3.7021	.2584
.17	.0589	.1724	.0061	.50	.1964	1.3955	.0833	.83	.4638	3.8061	.2653
.18	.0626	.1928	.0070	.51	.2014	1.4493	.0873	.84	.4803	3.9144	.2723
.19	.0662	.2144	.0080	.52	.2065	1.5041	.0914	.85	.4982	4.0276	.2794
.20	.0699	.2371	.0091	.53	.2117	1.5598	.0956	.86	.5177	4.1465	.2865
.21	.0736	.2609	.0103	.54	.2170	1.6164	.0998	.87	.5392	4.2721	.2938
.22	.0773	.2857	.0115	.55	.2224	1.6735	.1042	.88	.5632	4.4056	.3011
.23	.0811	.3116	.0128	.56	.2279	1.7327	.1087	.89	.5900	4.5486	.3084
.24	.0848	.3386	.0143	.57	.2335	1.7923	.1133	.90	.6204	4.7033	.3158
.25	.0887	.3667	.0157	.58	.2393	1.8530	.1179	.91	.6555	4.8725	.3233
.26	.0925	.3957	.0173	.59	.2451	1.9146	.1227	.92	.6966	5.0603	.3308
.27	.0963	.4259	.0190	.60	.2511	1.9773	.1276	.93	.7459	5.2726	.3384
.28	.1002	.4571	.0207	.61	.2572	2.0409	.1326	.94	.8065	5.5183	.3460
.29	.1042	.4893	.0226	.62	.2635	2.1057	.1376	.95	.8841	5.8118	.3537
.30	.1081	.5225	.0255	.63	.2699	2.1716	.1428	.96	.9885	6.1787	.3615
.31	.1121	.5568	.0266	.64	.2765	2.2386	.1481	.97	1.1410	6.6692	.3692
.32	.1161	.5921	.0287	.65	.2833	2.3067	.1534	.98	1.3958	7.4063	.3770
.33	.1202	.6284	.0309	.66	.2902	2.3760	.1589	.99	1.9700	8.8263	.3848
								1.00	....	....	.3927

HOW TO USE

Enter the table, either from the left column or from the top, at the known dimension. Move along the line until it intersects at right angles with the desired conversion dimension. Note the number at the intersection and follow instructions in blocks A or B.

A—Preferred Method

Enter table here and multiply by intersecting number. E.g. to convert 90 yards into feet, multiply by 3. Answer is 270 feet. Note: Figures in vertical columns indicate quantity of the left side dimension that equals one unit of the top symbol. E.g. 3 feet equals 1 yard.

B—Alternate Method

Enter table here and divide by intersecting number. E.g. to convert 270 feet into yards, divide by 3. Answer is 90 yards.

Name	SYMBOL							
	mm.	cm.	in.	dm.	ft.	yd.	m.	rd.
millimeters	1	10	25.4	100	304.8	913.4	1000	5029.2
centimeters	.1	1	2.54	10	30.48	91.44	100	502.9
inches	.03937	.3937	1	3.937	12	36	39.37	198
decimeters	.01	.1	.254	1	3.048	9.144	10	50.29
feet	.00328	.0328	.08333	.32808	1	3	3.2808	16.5
yards	.00109	.01093	.0278	.10936	.33333	1	1.0936	5.5
meters	.001	.01	.02540	.1	.30480	.91440	1	5.0297
rods	1.99x10 [illegible]		.00505	[illegible]	[illegible]	.18181	[illegible]	1
chains								

TABLE 9

CONVERSION TABLE

LENGTHS

Name	SYMBOL													
	mm.	cm.	in.	dm.	ft.	yd.	m.	rd.	ch.	hm.	fur.	km.	mi.	naut.mi *
millimeters	1	10	25.4	100	304.8	914.4	1000	5029.2	20116.8	100,000	201,168	1,000,000	1,609,347	1,853,248
centimeters	.1	1	2.54	10	30.48	91.44	100	502.9	2011.68	10,000	20116.8	100,000	160,935	185,325
inches	.03937	.3937	1	3.937	12	36	39.37	198	792	3937	7920	39,370	63,360	72,963
decimeters	.01	.1	.254	1	3.048	9.144	10	50.29	201.17	1000	2011.7	10,000	16,093	18,532
feet	.00328	.0328	.08333	.32808	1	3	3.2808	16.5	66	328.08	660	3280.8	5280	6080.2
yards	.00109	.01093	.0278	.10936	.33333	1	1.0936	5.5	22	109.36	220	1093.6	1760	2026.8
meters	.001	.01	.02540	.1	.30480	.91440	1	5.0292	20.116	100	201.17	1000	1609.3	1853.2
rods	1.99×10^{-4}	.00199	.00505	.01988	.0606	.18181	.1988	1	4	19.883	40	198.83	320	368.85
chains	4.97×10^{-5}	4.97×10^{-4}	.00126	.00497	.01515	.04545	.04971	.25	1	4.9708	10	49.708	80	92.23
hectometers	10^{-5}	10^{-4}	.00025	.001	.00305	.00914	.01	05029	.20117	1	2.0117	10	16.093	18.53
furlongs	4.97×10^{-6}	4.97×10^{-5}	1.26×10^{-4}	4.97×10^{-4}	.00151	.00454	.00497	.025	.1	.49078	1	4.9708	8	9.223
kilometers	10^{-6}	10^{-5}	2.54×10^{-5}	10^{-4}	3.05×10^{-4}	9.15×10^{-4}	.001	.00505	.02012	.1	.20117	1	1.6093	1.853
miles	6.21×10^{-7}	6.21×10^{-6}	1.58×10^{-5}	6.21×10^{-4}	1.89×10^{-4}	5.68×10^{-4}	6.21×10^{-4}	.00312	.0125	.06213	.125	.62137	1	1.151
nautical miles	5.39×10^{-7}	5.39×10^{-6}	1.37×10^{-5}	5.39×10^{-4}	1.64×10^{-4}	4.92×10^{-4}	5.39×10^{-4}	.00271	.01084	.05396	.10844	.5396	.8684	1

*Value adopted by the U. S. Coast and Geodeic Survey. A speed of 1 nautical mile per hour is called a knot.

CONVERSION TABLE

AREAS

Name	SYMBOL										
	cm^2.	sq. in.	sq. ft.	sq. yd.	m^2.	sq. rd.	sq. ch.	a.	ha.	km^2.	sq. mi.
square centimeters.....	1	6.452	929	8361	10^4	252,908	4,046,528	40,465,284	10^8	10^{10}	2.59×10^{10}
square inches..........	.155	1	144	1296	1550	39,204	627,264	6,272,640	155×10^5	155×10^7	4,014,489,600
square feet...........	1.076×10^{-3}	.00694	1	9	10.76	272.25	4356	43,560	107,639	10,763,900	27,878,400
square yards.........	1.196×10^{-4}	7.716×10^{-4}	.1111	1	1.196	30.25	484	4840	11.960	1,195,900	3,097,600
square meters.........	10^{-4}	6.452×10^{-4}	.0929	.8361	1	25.29	404.7	4047	10^4	10^6	2,589,998
square rods...........	3.953×10^{-6}	2.551×10^{-6}	3.673×10^{-3}	.03306	.0395	1	16	160	395.37	39,537	102,400
square chains.........	2.471×10^{-7}	1.594×10^{-8}	2.296×10^{-4}	.00207	.00247	.0625	1	10	24.71	2471	6400
acres.................	2.471×10^{-8}	1.594×10^{-7}	2.296×10^{-5}	2.066×10^{-4}	2.471×10^{-4}	.00625	.10	1	2.47104	247.1	640
hectares..............	10^{-8}	6.452×10^{-8}	9.29×10^{-6}	8.361×10^{-5}	10^{-4}	.00253	.04047	.4047	1	100	259
square kilometers.....	10^{-10}	6.452×10^{-10}	9.29×10^{-8}	8.361×10^{-7}	10^{-6}	2.529×10^{-5}	4.047×10^{-4}	4.047×10^{-3}	.01	1	2.59
square miles..........	3.861×10^{-11}	2.491×10^{-10}	3.587×10^{-8}	3.228×10^{-7}	3.861×10^{-7}	9.766×10^{-6}	1.563×10^{-4}	1.563×10^{-3}	3.861×10^{-3}	.3861	1

Time Equivalents

Days	Hours	Minutes	Seconds
1	24	1,440	86,400
0.04167	1	60	3,600
0.0006944	0.01667	1	60
0.00001157	0.0002777	0.01667	1

CONVERSION TABLES

VOLUMES

Name	SYMBOL										
	cm^3.	cu. in.	l.	U. S. gal.	imp. gal.	cu. ft.	cu. yds.	m^3.	ac. ft.	s. f. d.	m. g.
cubic centimeters.....	1	16.39	1000	3785.4	4542.5	28,317	764,560	10^6	1.233×10^9	2.451×10^9	3.785×10^9
cubic inches..........	.06102	1	61.0234	231	277.274	1728	46,656	61,023	75,271,680	149,299,200	231×10^6
liters................	.001	.016387	1	3.7854	4.5425	28.317	764.56	1000	1,233,490	2,451,250	3,785,430
U. S. gallons.........	2.642×10^{-4}	.004329	.26417	1	1.200	7.4805	201.974	264.17	325,851	646.317	10^6
imperial gallons......	2.201×10^{-4}	.003607	.22008	.83311	1	6.2321	168.267	220.083	271,472	538,453	833,111
cubic feet............	3.531×10^{-5}	5.787×10^{-4}	.03531	.13368	.16046	1	27	35.3145	43,560	86,400	133,681
cubic yards...........	1.308×10^{-6}	2.143×10^{-5}	.001308	.00495	.00594	.03704	1	1.30794	1613.33	3200	4951
cubic meters..........	10^{-6}	1.639×10^{-5}	.001	.003785	.00454	.02832	.76456	1	1233.49	2451.25	3785
acre feet.............	8.107×10^{-10}	1.328×10^{-8}	8.107×10^{-7}	3.069×10^{-6}	3.684×10^{-6}	2.296×10^{-5}	6.199×10^{-4}	8.107×10^{-4}	1	1.9835	3.0684
second-foot-day.......	4.081×10^{-10}	6.698×10^{-9}	4.081×10^{-7}	1.547×10^{-6}	1.588×10^{-6}	1.157×10^{-5}	3.125×10^{-4}	4.081×10^{-4}	.5042	1	1.5472
million U. S. gallons.	2.644×10^{-10}	[illegible]	2.644×10^{-7}	10^{-6}	1.2×10^{-6}	7.481×10^{-6}	[illegible]	2.642×10^{-4}	.3069	[illegible]	1

CONVERSION TABLES

FLOW

VOLUME PER TIME

Name	SYMBOL: gal. per day U.S.	gal. per day imp.	cu. ft. per day	m^3 per day	gal. per min. U.S.	gal. per min. imp.	l/sec.	gal. per sec. U.S.	gal. per sec. imp.	ac. ft. per day	sec. ft. or cusec.	m^3/sec.
U.S. gallons per day...	1	1.200	7.4805	264.17	1440	1728	22,824	86,400	103,680	325,850	646,323	22,824,288
imp. gallons per day....	.8333	1	6.233	220.14	1200	1440	19,020	72,000	86,400	271,542	538,860	19,020,240
cubic feet per day.	.1337	.1605	1	35.314	192.50	231.12	3051.2	11,550	13,860	43,560	86,400	3,051,173
cubic meters per day ...	.003785	.004544	.02832	1	5.451	6.541	86.4	327.06	392.47	1233.5	2446.6	86,400
U.S. gals. per minute...	6.944×10^{-4}	8.333×10^{-4}	5.195×10^{-3}	.1835	1	1.200	15.850	60	72	226.28	443.83	15,850
imp. gals. per minute ...	5.787×10^{-4}	6.944×10^{-4}	4.327×10^{-3}	.1528	.8333	1	13.208	50	60	188.57	374.03	13,208
liters per second........	4.382×10^{-6}	5.258×10^{-5}	3.278×10^{-4}	.0116	.0631	.0757	1	3.785	4.542	14.276	28.317	1000
U.S. gals. per second ..	1.157×10^{-5}	1.389×10^{-5}	8.658×10^{-5}	3.057×10^{-3}	.01667	.02	.2643	1	1.2	3.771	7.480	264.2
imp.gals. per second.....	9.647×10^{-6}	1.157×10^{-5}	7.215×10^{-5}	2.548×10^{-3}	.01389	.01667	.2201	.8333	1	3.142	6.232	220.1
acre feet per day........	3.069×10^{-6}	3.683×10^{-6}	2.296×10^{-5}	8.106×10^{-4}	.00442	.00530	.0700	.2652	.3183	1	1.9835	70.045
cubic feet per second.....	1.548×10^{-6}	1.856×10^{-6}	1.157×10^{-5}	4.088×10^{-4}	.00223	.00267	.0353	.1337	.1605	.5042	1	35.314
cubic meters per second.	4.381×10^{-8}	5.258×10^{-8}	3.278×10^{-7}	1.157×10^{-5}	6.309×10^{-6}	7.572×10^{-5}	.001	.00378	.00454	.0143	.0283	1

Pressure Equivalents

Pounds per Square Inch	Atmospheres	Column of Hg @ 32°F Inches
1	0.06805	2.036
14.696	1	29.92
0.4912	0.03342	1

CONVERSION TABLE

CUBIC FEET TO LITERS AND CUBIC FEET PER SECOND TO LITERS PER SECOND

Tens	UNITS: 0	1	2	3	4	5	6	7	8	9
0	....	28.317	56.634	84.951	113.268	141.585	169.902	198.219	226.536	254.853
1	283.170	311.487	339.804	368.121	396.438	424.755	453.072	481.389	509.706	538.023
2	566.340	594.657	622.974	651.291	679.608	707.925	736.242	764.559	792.876	821.193
3	849.510	877.827	906.144	934.461	962.778	991.095	1,019.412	1,047.729	1,076.046	1,104.363
4	1,132.680	1,160.997	1,189.314	1,217.631	1,245.948	1,274.265	1,302.582	1,330.899	1,359.216	1,387.533
5	1,415.850	1,444.167	1,472.484	1,500.801	1,529.118	1,557.435	1,585.752	1,614.069	1,642.386	1,670.703
6	1,699.020	1,727.337	1,755.654	1,783.971	1,812.288	1,840.605	1,868.922	1,897.239	1,925.556	1,953.873
7	1,982.190	2,010.507	2,038.824	2,067.141	2,095.458	2,123.775	2,152.092	2,180.409	2,208.726	2,237.043
8	2,265.360	2,293.677	2,321.994	2,350.311	2,378.628	2,406.945	2,435.262	2,463.579	2,491.896	2,520.213
9	2,548.530	2,576.847	2,605.164	2,633.481	2,661.798	2,690.115	2,718.432	2,746.749	2,775.066	2,803.383

LITERS TO CUBIC FEET AND LITERS PER SECOND TO CUBIC FEET PER SECOND

Tens	UNITS: 0	1	2	3	4	5	6	7	8	9
0	....	0.035	0.071	0.106	0.141	0.177	0.212	0.247	0.283	0.318
1	0.352	0.389	0.424	0.459	0.494	0.530	0.565	0.600	0.636	0.671
2	0.706	0.742	0.777	0.812	0.847	0.883	0.918	0.954	0.989	1.024
3	1.060	1.095	1.130	1.166	1.201	1.236	1.272	1.307	1.342	1.377
4	1.413	1.448	1.483	1.519	1.554	1.589	1.625	1.660	1.695	1.731
5	1.766	1.801	1.837	1.872	1.907	1.943	1.978	2.013	2.049	2.084
6	2.119	2.155	2.190	2.225	2.260	2.296	2.331	2.366	2.402	2.437
7	2.472	2.508	2.543	2.578	2.614	2.649	2.684	2.720	2.755	2.790
8	2.826	2.861	2.896	2.932	2.967	3.002	3.038	3.073	3.108	3.143
9	3.179	3.214	3.249	3.285	3.320	3.355	3.391	3.426	3.461	3.497

CONVERSION TABLE

CUBIC FEET PER SECOND TO U. S. GALLONS PER MINUTE

Tens	UNITS 0	1	2	3	4	5	6	7	8	9
0	....	448.83	897.66	1,346.49	1,795.32	2,244.15	2,692.98	3,141.81	3,590.64	4,039.47
1	4,488.30	4,937.13	5,385.96	5,834.79	6,283.62	6,732.45	7,181.28	7,630.11	8,078.94	8,527.77
2	8,976.60	9,425.43	9,874.26	10,323.09	10,771.92	11,220.75	11,669.58	12,118.41	12,567.24	13,016.07
3	13,464.90	13,913.73	14,362.56	14,811.39	15,260.22	15,709.05	16,157.88	16,606.71	17,055.54	17,504.37
4	17,953.20	18,402.03	18,850.86	19,299.69	19,748.52	20,197.35	20,646.18	21,095.01	21,543.84	21,992.67
5	22,441.50	22,890.33	23,339.16	23,787.99	24,236.82	24,685.65	25,134.48	25,583.31	26,032.14	26,480.97
6	26,929.80	27,378.63	27,827.46	28,276.29	28,725.12	29,173.95	29,622.78	30,071.61	30,520.44	30,969.27
7	31,418.10	31,866.93	32,315.76	32,764.59	33,213.42	33,662.25	34,111.08	34,559.91	35,008.74	35,457.57
8	35,906.40	36,355.23	36,804.06	37,252.89	37,701.72	38,150.55	38,599.38	39,048.21	39,497.04	39,945.87
9	40,394.70	40,843.53	41,292.36	41,741.19	42,190.02	42,638.85	43,087.68	43,536.51	43,985.34	44,434.17

U. S. GALLONS PER MINUTE TO CUBIC FEET PER SECOND

Tens	UNITS 0	1	2	3	4	5	6	7	8	9
0	....	0.00223	0.00446	0.00668	0.00891	0.01114	0.01337	0.01560	0.01782	0.02005
1	0.02228	0.02451	0.02674	0.02896	0.03119	0.03342	0.03565	0.03788	0.04010	0.04233
2	0.04456	0.04679	0.04902	0.05124	0.05347	0.05570	0.05793	0.06016	0.06238	0.06461
3	0.06684	0.06907	0.07130	0.07352	0.07575	0.07798	0.08021	0.08244	0.08466	0.08689
4	0.08912	0.09135	0.09358	0.09580	0.09803	0.10026	0.10249	0.10472	0.10694	0.10917
5	0.11140	0.11363	0.11586	0.11808	0.12031	0.12254	0.12477	0.12700	0.12922	0.13145
6	0.13368	0.13591	0.13814	0.14036	0.14259	0.14482	0.14705	0.14928	0.15150	0.15373
7	0.15596	0.15819	0.16042	0.16264	0.16487	0.16710	0.16933	0.17156	0.17378	0.17601
8	0.17824	0.18047	0.18270	0.18492	0.18715	0.18938	0.19161	0.19384	0.19606	0.19829
9	0.20052	0.20275	0.20498	0.20720	0.20493	0.21166	0.21389	0.21612	0.21384	0.22057

CONVERSION TABLES

CUBIC FEET PER SECOND TO MILLION U. S. GALLONS PER DAY

Tens	UNITS 0	1	2	3	4	5	6	7	8	9
0	....	0.646	1.293	1.939	2.585	3.232	3.878	4.524	5.170	5.817
1	6.463	7.109	7.756	8.402	9.048	9.695	10.341	10.987	11.633	12.280
2	12.926	13.572	14 219	14.865	15.511	16.158	16.804	17.450	18.096	18.743
3	19.389	20.035	20.682	21.328	21.974	22.621	23.267	23.913	24.559	25.206
4	25.852	26.498	27.145	27.791	28.437	29.084	29.730	30.376	31.022	31.669
5	32.315	32.961	33.608	34.254	34.900	35.547	36.193	36.839	37.485	38.132
6	38.778	39.424	40.071	40.717	41.363	42.010	42.656	43.302	43.948	44.595
7	45.241	45.887	46.534	47.180	47.826	48.473	49.119	49.765	50.411	51.058
8	51.704	52.350	52.997	53.643	54.289	54.936	55.582	56.228	56.874	57.521
9	58.167	58.813	59.460	60.106	60.752	61.399	62.045	62.691	63.337	63.984

MILLION U. S. GALLONS PER DAY TO CUBIC FEET PER SECOND

Tens	UNITS 0	1	2	3	4	5	6	7	8	9
0	....	1.547	3.094	4.642	6.189	7.736	9.283	10.830	12.378	13.925
1	15.472	17.019	18.566	20.114	21.661	23.208	24.755	26.302	27.850	29.397
2	30.944	32.491	34.038	35.586	37.133	38.680	40.227	41.774	43.322	44.869
3	46.416	47.963	49.510	51.058	52.605	54.152	55.699	57.246	58.794	60.341
4	61.888	63.435	64.982	66.530	68.077	69.624	71.171	72.718	74.266	75.813
5	77.360	78.907	80.454	82.002	83.549	85.096	86.643	88.190	89.738	91.285
6	92.832	94.379	95.926	97.474	99.021	100.568	102.115	103.662	105.210	106.757
7	108.304	109.851	111.398	112.946	114.493	116.040	117.587	119.134	120.682	122.229
8	123.776	125.323	126.870	128.418	129.965	131.512	133.059	134.606	136.154	137.701
9	139.248	140.795	142.342	143.890	145.437	146.984	148.531	150.078	151.626	153.173

Temperature Conversion Formulas

Degrees Celsius (formerly Centigrade) C	Degrees Fahrenheit-F
(Cx9/5)+32 = F Fahrenheit	(F-32)x5/9 = C Celsius

Conversion Table for Centigrade to Fahrenheit Temperatures

(-19°C to 39°C)

Temp. $^{\circ}$C	0	1	2	3	4	5	6	7	8	9
-10	+14.0	12.2	10.4	8.6	6.8	5.0	3.2	+1.4	-0.4	-2.2
0	+32.0	30.2	28.4	26.6	24.8	23.0	21.2	19.4	17.6	15.8
0	32.0	33.8	35.6	37.4	39.2	41.0	42.8	44.6	46.4	48.2
10	50.0	51.8	53.6	55.4	57.2	59.0	60.8	62.6	64.4	66.2
20	68.0	69.8	71.6	73.4	75.2	77.0	78.8	80.6	82.4	84.2
30	86.0	87.8	89.6	91.4	93.2	95.0	96.8	98.6	100.4	102.2

Miscellaneous Conversions

This:	Times This:	Gives You This:
cfs	1.983	AF per day
cfs	724.0	AF per year (365 days)
csm	0.03719	inches depth per day
csm	13.57	inches depth per year (365 days)
inches depth	53.33	AF per square mile
AF	0.01875	inches depth on 1 square mile
AF per day	0.5042	cfs
AF per square mile	0.01875	inches depth
feet per second	0.6818	miles per hour
hectares	2.471	acres

cfs = cubic feet per second
AF = acre feet
csm = cubic feet per second per square mile

Soil Moisture -

weight of 1 acre inch of non-stony loam soil (completely dry)	300,000 lbs.
weight of 1 acre inch of water at 4°C	226,621 lbs.
weight of 1 acre inch of non-stony loam soil at wilting point (1" water/12" soil)	318,900 lbs.
weight of 1 acre inch same soil at field capacity (3" water/12" soil)	356,700 lbs.
plant available water/acre inch of same soil	37,800 lbs. or 4,530 gallons

Mass Equivalents

Grams	Ounces	Pounds	Kilograms	Tons (Short)
1	0.035274	0.0022046	0.0010	0.000001102
28.35	1	0.06250	0.02835	0.00003125
453.6	16	1	0.4536	0.00050
1,000	35.27	2.2046	1	0.001102
907,190	32,000	2,000	907.2	1

Miscellaneous Equivalents

1 part per million (ppm) = 1 milligram per liter (mg/1) = 8.34 lbs. per million gallons
1 part per billion (ppb) = 1 microgram per liter (ug/1)
part per million by weight= $\frac{\text{mg/1}}{\text{Specific Gravity}}$

Volume and Capacity Equivalents

Cubic Inches	Cubic Feet	Cubic Yards	Liters	Quarts Liquid	Gallons U.S. Liq.	Gallons Imperial	Pounds of Water @ 4°C
1	0.0005787	0.00002143	0.016387	0.01732	0.004329	0.003605	0.03613
1,728	1	0.03704	28.32	29.92	7.481	6.229	62.43
46,656	27	1	764.6	807.90	201.97	168.17	1,685.5
61.024	0.035315	0.001308	1	1.057	0.2642	0.220	2.205
57.75	0.03342	0.001238	0.9463	1	0.25	0.2082	2.086
231	0.13368	0.004951	3.785	4	1	0.8327	8.345
277.4	0.16054	0.005946	4.546	4.804	1.201	1	10.022
27.68	0.01602	0.0005933	0.5436	0.4793	0.1198	0.09978	1

Map Scales and Equivalents

1:m	Feet per inch	In. per 1000 ft.	Inches per Mile	Miles per in.	Meters per in.	Acres per sq. inch	Sq.in. per acre	Sq.mi. per sq.inch	cm per km
1: 500	41.667	24.00	126.72	0.008	12.700	0.0399	25.091	0.00006	200.00
1: 1200	100.00	10.00	52.80	0.019	30.480	0.2296	4.356	0.00036	83.33
1: 12000	1000.00	1.0	5.280	0.189	304.801	22.957	0.044	0.0359	8.333
1: 15840	1320.00	0.758	4.00	0.250	402.337	40.000	0.025	0.0625	6.313
1: 20000	1666.667	0.60	3.168	0.316	508.002	63.769	0.016	0.0996	5.000
1: 63360	5280.00	0.189	1.000	1.000	1609.347	640.00	0.0016	1.0000	1.578

TABLE 11

HANDY CONVERSIONS

To Convert	Multiply by	To obtain
Acres	4.356×10^{4}	square feet
Acres	4047	square meters
Acre-foot	2,720,000	foot-pounds
Acre-foot	1.372	horsepower-hours
Acre-foot	1.025	kilowatt-hours
Acre-foot	3496	British Thermal Units
Atmospheres	33.90	feet of water @ 4°C
Atmospheres	29.92	inches mercury @ 0°C
Atmospheres	1.033×10^{4}	kg per sq. meter
Atmospheres	14.70	Pounds per sq. inch
BTU	778.3	foot-pounds
BTU	.000393	horsepower-hours
BTU	.000293	horsepower-hours
BTU	.2520	kilogram-calories
Bushels	1.2445	cubic feet
Centimeters	3.381×10^{-2}	feet
Centimeters	.3937	inches
Cubic feet/second	40	Miner's inches by statute in California, Arizona, Montana, and Oregon
Cubic feet/second	50	Miner's inches by statute in Idaho, Nebraska, Nevada, New Mexico, North Dakota, South Dakota and Utah
Cubic feet/second	38.4	Miner's inches by statute in Colorado
Cubic feet/second	35.7	Miner's inches by statute in British Columbia
Cubic feet	.8036	bushels
Cubic feet	7.481	U.S. gallons
Cubic feet	62.38	pounds of water
Cubic feet	28.32	liters
Cubic feet	2.832×10^{-2}	cubic meters
Cubic inches	4.329×10^{-3}	U.S. gallons
Cubic inches	.0361	pounds of water
Cubic meters	35.31	cubic feet
fathoms	6	feet
feet	30.48	centimeters
feet	.16667	fathoms
feet	3.048×10^{-4}	kilometers
foot-pounds	5.050×10^{-7}	horsepower-hours
Gallon U.S.	3.785×10^{-3}	cubic meters
Gallon U.S.	.1337	cubic feet
Gallon U.S.	.8327	Imperial gallons
Gallon U.S.	231	cubic inches
Gallon Imperial	1.201	U.S. gallons
Horsepower	550	ft.-lb. per second
inches	2.540	centimeters
kilograms	2.205	pounds
kilometers	3281	feet
kilowatt	1.341	horsepower
kilowatt	737	ft.-lb. per second
kilowatt	102	kilogram-meters per second
kilowatt	746	watts
knots	1.1508	miles per hour
links	.01	chains
links	7.92	inches
liters	.2642	U.S. gallons
liters	3.531×10^{-2}	cubic feet
meters	1.094	yards
miles	5280	feet
miles	1.609	kilometers
ounces	3.125×10^{-2}	quarts
pounds water	1.603×10^{-2}	cubic feet
quarts	.25	U.S. gallons
quarts	32	ounces
rods	16.5	feet
square inches	6.452	sq. centimeters
square feet	9.290×10^{-2}	sq. meters
square feet	2.296×10^{-5}	acres
square miles	3.098×10^{6}	sq. yards
square miles	640	acres
square miles	2.590	sq. kilometers
tons, long	2240	pounds
tons, long	1.120	tons, short
tons, short	2000	pounds
tons, short	.8929	tons, long
tons, short	40	cubic feet
watts	5.689×10^{-2}	BTU per minute
watts	44.26	ft.-lb. per minute
yards	3	feet
yards	.9144	meters

Table 4.—Acre-feet equivalent to a given number of second-feet flowing for a given length of time. (See sec. 3.)

Second-feet	Minutes			Hours														
	15	30	45	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.01	0.0002	0.0004	0.0006	0.0008	0.0017	0.0025	0.0033	0.0041	0.0050	0.006	0.007	0.007	0.008	0.009	0.010	0.011	0.012	0.012
.02	.0004	.0008	.0012	.0017	.0033	.0050	.0066	.0083	.0099	.012	.013	.015	.017	.018	.020	.021	.023	.025
.03	.0006	.0012	.0019	.0025	.0050	.0074	.0099	.0124	.0149	.017	.020	.022	.025	.027	.030	.032	.035	.037
.04	.0008	.0017	.0025	.0033	.0066	.0099	.0132	.0165	.0198	.023	.026	.030	.033	.036	.040	.043	.046	.050
.05	.0010	.0021	.0031	.0041	.0083	.0124	.0165	.0207	.0248	.029	.033	.037	.041	.045	.050	.054	.058	.062
.06	.0012	.0025	.0037	.0050	.0099	.0149	.0198	.0248	.0298	.035	.040	.045	.050	.055	.060	.064	.069	.074
.07	.0015	.0029	.0043	.0058	.0116	.0174	.0231	.0289	.0347	.040	.046	.052	.058	.064	.069	.075	.081	.087
.08	.0017	.0033	.0050	.0066	.0132	.0198	.0265	.0331	.0397	.046	.053	.060	.066	.073	.079	.086	.093	.099
.09	.0019	.0037	.0056	.0074	.0149	.0223	.0298	.0372	.0446	.052	.060	.067	.074	.082	.089	.097	.104	.112
.10	.0021	.0041	.0062	.0083	.0165	.0248	.0331	.0413	.0496	.058	.066	.074	.083	.091	.099	.107	.116	.124
.11	.0023	.0046	.0068	.0091	.0182	.0273	.0364	.0455	.0546	.064	.073	.082	.091	.100	.109	.118	.127	.136
.12	.0025	.0050	.0074	.0099	.0198	.0298	.0397	.0496	.0595	.069	.079	.089	.099	.109	.119	.129	.139	.149
.13	.0027	.0054	.0081	.0107	.0215	.0322	.0430	.0537	.0645	.075	.086	.097	.107	.118	.129	.140	.150	.161
.14	.0029	.0058	.0087	.0116	.0231	.0347	.0463	.0579	.0694	.081	.093	.104	.116	.127	.139	.150	.162	.174
.15	.0031	.0062	.0093	.0124	.0248	.0372	.0496	.0620	.0744	.087	.099	.112	.124	.136	.149	.161	.174	.186
.16	.0033	.0066	.0099	.0132	.0265	.0397	.0529	.0661	.0793	.093	.106	.119	.132	.145	.159	.172	.185	.198
.17	.0035	.0070	.0105	.0141	.0281	.0422	.0562	.0703	.0843	.098	.112	.126	.140	.155	.169	.183	.197	.211
.18	.0037	.0074	.0112	.0149	.0298	.0446	.0595	.0744	.0893	.104	.119	.134	.149	.164	.179	.193	.208	.223
.19	.0039	.0079	.0118	.0157	.0314	.0471	.0628	.0785	.0942	.110	.126	.141	.157	.173	.188	.204	.220	.236
.20	.0041	.0083	.0124	.0165	.0331	.0496	.0661	.0826	.0992	.116	.132	.149	.165	.182	.198	.215	.231	.248
.21	.0043	.0087	.0130	.0174	.0347	.0521	.0694	.0868	.1041	.121	.139	.156	.174	.191	.208	.226	.243	.260
.22	.0046	.0091	.0136	.0182	.0364	.0546	.0727	.0909	.1091	.127	.145	.164	.182	.200	.218	.236	.255	.273
.23	.0048	.0095	.0143	.0190	.0380	.0570	.0760	.0950	.1141	.133	.152	.171	.190	.209	.228	.247	.266	.285
.24	.0050	.0099	.0149	.0198	.0397	.0595	.0793	.0992	.1190	.139	.159	.179	.198	.218	.238	.258	.278	.298
.25	.0052	.0103	.0155	.0207	.0413	.0620	.0826	.1033	.1240	.145	.165	.186	.207	.227	.248	.269	.289	.310
.26	.0054	.0107	.0161	.0215	.0430	.0645	.0860	.1074	.1289	.150	.172	.193	.215	.236	.258	.279	.301	.322
.27	.0056	.0112	.0167	.0223	.0446	.0669	.0893	.1116	.1339	.156	.179	.201	.223	.245	.268	.290	.312	.335
.28	.0058	.0116	.0174	.0231	.0463	.0694	.0926	.1157	.1388	.162	.185	.208	.231	.255	.278	.301	.324	.347
.29	.0060	.0120	.0180	.0240	.0479	.0719	.0959	.1198	.1438	.168	.192	.216	.240	.264	.288	.312	.336	.360
.30	.0062	.0124	.0186	.0248	.0496	.0744	.0992	.1240	.1488	.174	.198	.223	.248	.273	.298	.322	.347	.372
.31	.0064	.0128	.0192	.0256	.0512	.0769	.1025	.1281	.1537	.179	.205	.231	.256	.282	.307	.333	.359	.384
.32	.0066	.0132	.0198	.0265	.0529	.0793	.1058	.1322	.1587	.185	.212	.238	.264	.291	.317	.344	.370	.397
.33	.0068	.0136	.0205	.0273	.0546	.0818	.1091	.1364	.1636	.191	.218	.245	.273	.300	.327	.355	.382	.409
.34	.0070	.0141	.0211	.0281	.0562	.0843	.1124	.1405	.1686	.197	.225	.253	.281	.309	.337	.365	.393	.421
.35	.0072	.0145	.0217	.0289	.0579	.0868	.1157	.1446	.1736	.202	.231	.260	.289	.318	.347	.376	.405	.434

Table 4.—Acre-feet equivalent to a given number of second-feet flowing for a given length of time. (See sec. 3.)—Continued

Second-feet	Hours									Days of 24 hours								
	16	17	18	19	20	21	22	23	24	2	3	4	5	6	7	8	9	10
0.01	0.013	0.014	0.015	0.016	0.017	0.017	0.018	0.019	0.020	0.04	0.06	0.08	0.10	0.12	0.14	0.16	0.18	0.20
.02	.026	.028	.030	.031	.033	.035	.036	.038	.040	.08	.12	.16	.20	.24	.28	.32	.38	.40
.03	.040	.042	.045	.047	.050	.052	.055	.057	.060	.12	.18	.24	.30	.36	.42	.48	.54	.60
.04	.053	.056	.060	.063	.066	.069	.073	.076	.079	.16	.24	.32	.40	.48	.56	.63	.71	.79
.05	.066	.070	.074	.079	.083	.087	.091	.095	.099	.20	.30	.40	.50	.60	.69	.79	.89	.99
.06	.079	.084	.089	.094	.099	.104	.109	.114	.119	.24	.36	.48	.60	.71	.83	.95	1.07	1.19
.07	.093	.098	.104	.110	.116	.121	.127	.133	.139	.28	.42	.56	.69	.83	.97	1.11	1.25	1.39
.08	.106	.112	.119	.126	.132	.139	.145	.152	.159	.32	.48	.63	.79	.95	1.11	1.27	1.43	1.59
.09	.119	.126	.134	.141	.149	.156	.164	.171	.179	.36	.54	.71	.89	1.07	1.25	1.43	1.61	1.79
.10	.132	.140	.149	.157	.165	.174	.182	.190	.198	.40	.60	.79	.99	1.19	1.39	1.59	1.79	1.98
.11	.145	.155	.164	.173	.182	.191	.200	.209	.218	.44	.65	.87	1.09	1.31	1.53	1.75	1.96	2.18
.12	.159	.169	.179	.188	.198	.208	.218	.228	.238	.48	.71	.95	1.19	1.43	1.67	1.90	2.14	2.38
.13	.172	.183	.193	.204	.215	.226	.236	.247	.258	.52	.77	1.03	1.29	1.55	1.80	2.02	2.32	2.58
.14	.185	.197	.208	.220	.231	.243	.255	.266	.278	.56	.83	1.11	1.39	1.67	1.94	2.22	2.50	2.78
.15	.198	.211	.223	.236	.248	.260	.273	.285	.298	.60	.89	1.19	1.49	1.79	2.08	2.38	2.68	2.98
.16	.212	.225	.239	.251	.264	.278	.291	.304	.317	.63	.95	1.27	1.59	1.90	2.22	2.54	2.86	3.17
.17	.225	.239	.253	.267	.281	.295	.309	.323	.337	.67	1.01	1.35	1.69	2.02	2.36	2.70	3.03	3.37
.18	.238	.253	.268	.283	.298	.312	.327	.342	.357	.71	1.07	1.43	1.79	2.14	2.50	2.86	3.21	3.57
.19	.251	.267	.283	.298	.314	.330	.345	.361	.377	.75	1.13	1.51	1.88	2.26	2.64	3.01	3.39	3.77
.20	.264	.281	.298	.314	.331	.347	.364	.380	.397	.79	1.19	1.59	1.98	2.38	2.78	3.17	3.57	3.97
.21	.278	.295	.312	.330	.347	.364	.382	.399	.417	.83	1.25	1.67	2.08	2.50	2.92	3.33	3.75	4.17
.22	.291	.309	.327	.345	.364	.382	.400	.418	[illegible]	.87	1.31	[illegible]	2.18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.23	.304	.323	[illegible]	.361	.380	[illegible]	.418	.437	[illegible]	.91	1.37	1.83	2.28	2.74	3.10	3.65	4.11	4.56
.24	.317	.337	.357	.377	.397	.417	.436	.456	.476	.95	1.43	1.90	2.38	2.86	3.33	3.81	4.28	4.76
.25	.331	.351	.372	.393	.413	.434	.455	.475	.493	.99	1.49	1.98	2.48	2.98	3.47	3.97	4.46	4.96
.26	.344	.365	.387	.408	.430	.451	.473	.494	.516	1.03	1.55	2.06	2.58	3.09	3.61	4.13	4.64	5.16
.27	.357	.379	.402	.424	.446	.469	.491	.513	.536	1.07	1.61	2.14	2.68	3.21	3.75	4.28	4.82	5.36
.28	.370	.393	.417	.440	.463	.486	.509	.532	.555	1.11	1.67	2.22	2.78	3.33	3.89	4.44	5.00	5.55
.29	.383	.407	.431	.455	.479	.503	.527	.551	.575	1.15	1.73	2.30	2.88	3.45	4.03	4.60	5.18	5.75
.30	.397	.421	.446	.471	.496	.521	.545	.570	.595	1.19	1.79	2.38	2.98	3.56	4.17	4.76	5.35	5.95
.31	.410	.436	.461	.487	.512	.538	.564	.590	.615	1.23	1.84	2.46	3.07	3.69	4.30	4.92	4.53	6.15
.32	.423	.450	.476	.502	.529	.555	.582	.608	.635	1.27	1.90	2.54	3.17	3.81	4.44	5.08	5.71	6.35
.33	.436	.464	.491	.518	.545	.573	.600	.627	.655	1.31	1.96	2.62	3.27	3.93	4.58	5.24	5.89	6.55
.34	.450	.478	.506	.534	.562	.590	.618	.646	.674	1.35	2.02	2.70	3.37	4.05	4.72	5.40	6.07	6.74
.35	.463	.492	.521	.550	.579	.607	.636	.665	.694	1.39	2.08	2.78	3.47	4.17	4.86	5.55	6.25	6.94

Table 4.—Acre-feet equivalent to a given number of second-feet flowing for a given length of time. (See sec. 3.)—Continued

Second-feet	Minutes 15	Minutes 30	Minutes 45	Hours 1	Hours 2	Hours 3	Hours 4	Hours 5	Hours 6
0.36	0.0074	0.0149	0.0223	0.0298	0.0595	0.0893	0.1190	0.1488	0.1785
.37	.0076	.0153	.0229	.0306	.0612	.0917	.1223	.1529	.1835
.38	.0079	.0157	.0236	.0314	.0628	.0942	.1256	.1570	.1884
.39	.0081	.0161	.0242	.0322	.0645	.0967	.1289	.1612	.1934
.40	.0083	.0165	.0248	.0331	.0661	.0992	.1322	.1653	.1984
.41	.0085	.0169	.0254	.0339	.0678	.1017	.1355	.1694	.2033
.42	.0087	.0174	.0260	.0347	.0694	.1041	.1388	.1736	.2083
.43	.0089	.0178	.0267	.0355	.0711	.1066	.1422	.1777	.2132
.44	.0091	.0182	.0273	.0364	.0727	.1091	.1455	.1818	.2182
.45	.0093	.0186	.0279	.0372	.0744	.1116	.1488	.1860	.2231
.46	.0095	.0190	.0285	.0380	.0760	.1141	.1521	.1901	.2281
.47	.0097	.0194	.0291	.0388	.0777	.1165	.1554	.1942	.2331
.48	.0099	.0198	.0298	.0397	.0793	.1190	.1587	.1984	.2380
.49	.0101	.0203	.0304	.0405	.0810	.1215	.1620	.2025	.2430
.50	.0103	.0207	.0310	.0413	.0826	.1240	.1653	.2066	.2479
.51	.0105	.0211	.0316	.0422	.0843	.1265	.1686	.2107	.2529
.52	.0107	.0215	.0322	.0430	.0860	.1289	.1719	.2149	.2579
.53	.0110	.0219	.0329	.0438	.0876	.1314	.1752	.2190	.2628
.54	.0112	.0223	.0335	.0446	.0893	.1339	.1785	.2231	.2678
.55	.0114	.0227	.0341	.0455	.0909	.1364	.1818	.2273	.2727
.56	.0116	.0231	.0347	.0463	.0926	.1388	.1851	.2314	.2777
.57	.0118	.0236	.0353	.0471	.0942	.1413	.1884	.2355	.2826
.58	.0120	.0240	.0360	.0479	.0959	.1438	.1917	.2397	.2876
.59	.0122	.0244	.0366	.0488	.0975	.1463	.1950	.2438	.2926
.60	.0124	.0248	.0372	.0496	.0992	.1488	.1984	.2479	.2975
.61	.0126	.0252	.0378	.0504	.1008	.1512	.2017	.2521	.3025
.62	.0128	.0256	.0384	.0512	.1025	.1537	.2050	.2562	.3074
.63	.0130	.0260	.0391	.0521	.1041	.1562	.2083	.2603	.3124
.64	.0132	.0265	.0397	.0529	1058	.1587	.2116	.2645	.3174
.65	.0134	.0269	.0403	.0537	.1074	.1612	.2149	.2686	.3223
.66	.0136	.0273	.0409	.0546	.1091	.1636	.2182	.2727	.3273
.67	.0138	.0277	.0415	.0554	.1107	.1661	.2215	.2769	.3322
.68	.0141	.0281	.0422	.0562	.1124	.1686	.2248	.2810	.3372
.69	.0143	.0285	.0428	.0570	.1141	.1711	.2281	.2851	.3422
.70	.0145	.0289	.0434	.0579	.1157	.1736	.2314	.2893	.3471

Second-feet	Hours 7	Hours 8	Hours 9	Hours 10	Hours 11	Hours 12	Hours 13	Hours 14	Hours 15
0.36	0.208	0.238	0.208	0.298	0.327	0.357	0.387	0.417	0.446
.37	.214	.245	.275	.306	.336	.367	.398	.428	.459
.38	.220	.251	.283	.314	.345	.377	.408	.440	.471
.39	.226	.258	.290	.322	.355	.387	.419	.451	.483
.40	.231	.264	.298	.331	.364	.397	.430	.463	.496
.41	.237	.271	.305	.339	.373	.407	.440	.474	.508
.42	.243	.278	.312	.347	.382	.417	.451	.486	.521
.43	.249	.284	.320	.355	.391	.426	.462	.498	.533
.44	.255	.291	.327	.364	.400	.436	.473	.509	.545
.45	.260	.298	.335	.372	.409	.446	.483	.521	.558
.46	.266	.304	.342	.380	.418	.456	.494	.532	.570
.47	.272	.311	.350	.388	.427	.466	.505	.544	.583
.48	.278	.317	.357	.397	.436	.476	.516	.555	.595
.49	.283	.324	.364	.405	.445	.486	.526	.567	.607
.50	.289	.331	.372	.413	.455	.496	.537	.579	.620
.51	.295	.337	.379	.421	.464	.506	.548	.590	.632
.52	.301	.344	.387	.430	.473	.516	.559	.602	.645
.53	.307	.350	.394	.438	.482	.526	.569	.613	.657
.54	.312	.357	.402	.446	.491	.536	.580	.625	.669
.55	.318	.364	.409	.455	.500	.545	.591	.636	.682
.56	.324	.370	.417	.463	.509	.555	.602	.648	.694
.57	.330	.377	.424	.471	.518	.565	.612	.660	.707
.58	.336	.383	.431	.479	.527	.575	.623	.671	.719
.59	.342	.390	.439	.488	.536	.585	.634	.683	.731
.60	.347	.397	.446	.496	.545	.595	.645	.694	.744
.61	.353	.403	.454	.504	.555	.605	.655	.706	.756
.62	.359	.410	.461	.512	.564	.615	.666	.717	.769
.63	.364	.417	.469	.521	.573	.625	.677	.729	.781
.64	.370	.423	.476	.529	.582	.635	.688	.740	.793
.65	.376	.430	.483	.537	.591	.645	.698	.752	.806
.66	.382	.436	.490	.545	.600	.655	.709	.764	.818
.67	.388	.443	.498	.554	.609	.664	.720	.775	.831
.68	.393	.450	.506	.562	.618	.674	.731	.787	.843
.69	.399	.456	.513	.570	.627	.684	.741	.897	.855
.70	.405	.463	.521	.579	.636	.694	.752	.810	.868

Table 4.—Acre-feet equivalent to a given number of second-feet flowing for a given length of time. (See sec. 3.)—Continued

Second-feet	Hours 16	Hours 17	Hours 18	Hours 19	Hours 20	Hours 21	Hours 22	Hours 23	Hours 24
0.36	0.476	0.506	0.536	0.565	0.595	0.625	0.655	0.684	0.714
.37	.489	.520	.550	.581	.612	.642	.673	.703	.734
.38	.502	.534	.565	.597	.628	.660	.691	.722	.754
.39	.516	.548	.580	.612	.645	.677	.709	.741	.774
.40	.529	.562	.595	.628	.661	.694	.727	.760	.793
.41	.542	.576	.610	.644	.678	.712	.745	.779	.813
.42	.555	.590	.625	.660	.694	.729	.764	.798	.833
.43	.569	.604	.640	.675	.711	.746	.782	.817	.853
.44	.582	.618	.655	.691	.727	.764	.800	.836	.873
.45	.595	.632	.669	.707	.744	.781	.818	.855	.893
.46	.608	.646	.684	.722	.760	.798	.836	.874	.912
.47	.621	.660	.699	.738	.777	.816	.855	.893	.932
.48	.635	.674	.714	.754	.793	.833	.873	.912	.952
.49	.648	.688	.729	.769	.810	.850	.891	.931	.972
.50	.661	.702	.744	.785	.826	.868	.909	.950	.992
.51	.67	.72	.76	.80	.84	.89	.93	.97	1.01
.52	.69	.73	.77	.82	.86	.90	.95	.99	1.03
.53	.70	.74	.79	.83	.88	.92	.96	1.01	1.05
.54	.71	.76	.80	.85	.89	.94	.98	1.03	1.07
.55	.73	.77	.82	.86	.91	.95	1.00	1.05	1.09
.56	.74	.79	.83	.88	.93	.97	1.02	1.06	1.11
.57	.75	.80	.85	.90	.94	.99	1.04	1.08	1.13
.58	.77	.81	.86	.91	.96	1.01	1.05	1.10	1.15
.59	.78	.83	.88	[illegible]	.98	1.02	1.07	[illegible]	1.17
.60	.79	.84	.89	[illegible]	.99	1.04	1.09	1.14	1.19
.61	.81	.86	.91	.96	1.01	1.06	1.11	1.16	1.21
.62	.82	.87	.92	.97	1.02	1.08	1.13	1.18	1.23
.63	.83	.89	.94	.99	1.04	1.09	1.15	1.20	1.25
.64	.85	.90	.95	1.00	1.06	1.11	1.16	1.22	1.27
.65	.86	.91	.97	1.02	1.07	1.13	1.18	1.24	1.29
.66	.87	.93	.98	1.04	1.09	1.15	1.20	1.25	1.31
.67	.89	.94	1.00	1.05	1.11	1.16	1.22	1.27	1.33
.68	.90	.96	1.01	1.07	1.12	1.18	1.24	1.29	1.35
.69	.91	.97	1.03	1.08	1.14	1.20	1.25	1.31	1.37
.70	.93	.98	1.04	1.10	1.16	1.21	1.27	1.33	1.39

Second-feet	Days of 24 hours 2	Days 3	Days 4	Days 5	Days 6	Days 7	Days 8	Days 9	Days 10
0.36	1.43	2.14	2.86	3.57	4.28	5.00	5.71	6.43	7.14
.37	1.47	2.20	2.94	3.67	4.40	5.14	5.87	6.60	7.34
.38	1.51	2.26	3.01	3.77	4.52	5.28	6.03	6.78	7.54
.39	1.55	2.32	3.09	3.87	4.64	5.41	6.19	6.96	7.74
.40	1.50	2.38	3.17	3.97	4.76	5.55	6.35	7.14	7.93
.41	1.63	2.44	3.25	4.07	4.88	5.69	6.51	7.32	8.13
.42	1.67	2.50	3.33	4.17	5.00	5.83	6.66	7.50	8.33
.43	1.71	2.56	3.41	4.26	5.12	5.97	6.82	7.68	8.53
.44	1.75	2.62	3.49	4.36	5.24	6.11	6.98	7.85	8.73
.45	1.79	2.68	3.57	4.46	5.36	6.25	7.14	8.03	8.93
.46	1.82	2.74	3.65	4.56	5.47	6.39	7.30	8.21	9.12
.47	1.86	2.80	3.73	4.66	5.59	6.53	7.46	8.39	9.32
.48	1.90	2.86	3.81	4.76	5.71	6.66	7.62	8.57	9.52
.49	1.94	2.92	3.89	4.86	5.83	6.80	7.78	8.75	9.72
.50	1.98	2.98	3.97	4.96	5.95	6.94	7.93	8.93	9.92
.51	2.02	3.03	4.05	5.06	6.07	7.08	8.09	9.10	10.12
.52	2.06	3.09	4.13	5.16	6.19	7.22	8.25	9.28	10.31
.53	2.10	3.15	4.20	5.26	6.31	7.36	8.41	9.46	10.52
.54	2.14	3.21	4.28	5.36	6.43	7.50	8.57	9.64	10.71
.55	2.18	3.27	4.36	5.45	6.55	7.64	8.73	9.82	10.91
.56	2.22	3.33	4.44	5.55	6.66	7.78	8.80	10.00	11.11
.57	2.26	3.39	4.52	5.65	6.78	7.91	9.04	10.19	11.31
.58	[illegible]	[illegible]	[illegible]	5.75	[illegible]	8.05	[illegible]	10.35	[illegible]
.59	[illegible]	3.51	[illegible]	[illegible]	7.02	8.19	[illegible]	[illegible]	11.70
.60	2.38	3.57	4.76	5.95	7.14	8.33	9.52	10.71	11.90
.61	2.42	3.63	4.84	6.05	7.26	8.47	9.68	10.89	12.10
.62	2.46	3.69	4.92	6.15	7.38	8.61	9.84	11.07	12.30
.63	2.50	3.75	5.00	6.25	7.50	8.75	10.00	11.25	12.50
.64	2.54	3.81	5.08	6.35	7.62	8.89	10.16	11.42	12.69
.65	2.58	3.87	5.16	6.45	7.74	9.02	10.31	11.60	12.89
.66	2.62	3.93	5.24	6.55	7.85	9.16	10.47	11.78	13.09
.67	2.66	3.99	5.32	6.64	7.97	9.30	10.63	11.96	13.29
.68	2.70	4.05	5.40	6.74	8.09	9.44	10.79	12.14	13.49
.69	2.74	4.11	5.47	6.84	8.21	9.58	10.95	12.32	13.69
.70	2.78	4.17	5.55	6.94	8.33	9.71	11.11	12.50	13.88

Table 4.—Acre-feet equivalent to a given number of second-feet flowing for a given length of time. (See sec. 3.)—Continued

Second-feet	Minutes 15	Minutes 30	Minutes 45	Hours 1	Hours 2	Hours 3	Hours 4	Hours 5	Hours 6	Hours 7	Hours 8	Hours 9	Hours 10	Hours 11	Hours 12	Hours 13	Hours 14	Hours 15
0.71	0.0147	0.0293	0.0440	0.0587	0.1174	0.1760	0.2348	0.2934	0.3521	0.410	0.469	0.528	0.587	0.645	0.704	0.763	0.821	0.880
.72	.0149	.0298	.0446	.0595	.1190	.1785	.2380	.2975	.3570	.417	.476	.536	.595	.655	.714	.774	.833	.893
.73	.0151	.0302	.0453	.0603	.1207	.1810	.2413	.3017	.3620	.422	.483	.543	.603	.664	.724	.784	.845	.905
.74	.0153	.0306	.0459	.0612	.1223	.1835	.2446	.3058	.3669	.428	.489	.550	.612	.673	.734	.795	.856	.917
.75	.0155	.0310	.0465	.0620	.1240	.1860	.2479	.3099	.3719	.434	.496	.558	.620	.682	.744	.806	.868	.930
.76	.0157	.0314	.0471	.0628	.1256	.1884	.2512	.3141	.3769	.440	.502	.565	.628	.691	.754	.817	.879	.942
.77	.0159	.0318	.0477	.0636	.1273	.1909	.2546	.3182	.3818	.445	.509	.573	.636	.700	.764	.827	.891	.955
.78	.0161	.0322	.0484	.0645	.1289	.1934	.2579	.3223	.3868	.451	.516	.580	.645	.709	.774	.838	.902	.967
.79	.0163	.0326	.0490	.0653	.1306	.1959	.2612	.3265	.3917	.457	.522	.588	.653	.718	.783	.849	.914	.979
.80	.0165	.0331	.0496	.0661	.1322	.1984	.2645	.3306	.3967	.463	.529	.595	.661	.727	.793	.860	.926	.992
.81	.0167	.0335	.0502	.0669	.1339	.2008	.2678	.3347	.4017	.469	.535	.602	.669	.736	.803	.870	.937	1.004
.82	.0169	.0339	.0508	.0678	.1355	.2033	.2711	.3388	.4066	.474	.542	.610	.678	.745	.813	.881	.949	1.017
.83	.0172	.0343	.0515	.0686	.1372	.2058	.2744	.3430	.4116	.480	.549	.617	.686	.755	.823	.892	.960	1.029
.84	.0174	.0347	.0521	.0694	.1388	.2083	.2777	.3471	.4165	.486	.555	.625	.694	.764	.833	.902	.972	1.041
.85	.0176	.0351	.0527	.0703	.1405	.2107	.2810	.3512	.4215	.492	.562	.632	.702	.773	.843	.913	.983	1.054
.86	.0178	.0355	.0533	.0711	.1422	.2132	.2843	.3554	.4265	.498	.569	.640	.711	.782	.853	.924	.995	1.066
.87	.0180	.0360	.0539	.0719	.1438	.2157	.2876	.3595	.4314	.503	.575	.647	.719	.791	.863	.935	1.007	1.079
.88	.0182	.0364	.0546	.0727	.1455	.2182	.2909	.3636	.4364	.509	.582	.655	.727	.800	.873	.945	1.018	1.091
.89	.0184	.0368	.0552	.0736	.1471	.2207	.2942	.3678	.4413	.515	.588	.662	.736	.809	.883	.956	1.030	1.103
.90	.0186	.0372	.0558	.0744	.1488	.2231	.2975	.3719	.4463	.521	.595	.669	.744	.818	.893	.967	1.041	1.116
.91	.0188	.0376	.0564	.0752	.1504	.2256	.3008	.3760	.4512	.526	.602	.677	.752	.827	.902	.978	1.053	1.128
.92	.0190	.0380	.0570	.0760	.1521	.2281	.3041	.3802	.4562	.532	.608	.684	.760	.836	.912	.988	1.064	1.140
.93	.0192	.0384	.0576	.0769	.1537	.2306	.3074	.3843	.4612	.538	.615	.692	.769	.845	.922	.999	1.076	1.153
.94	.0194	.0388	.0583	.0777	.1554	.2331	.3107	.3884	.4661	.544	.621	.699	.777	.855	.932	1.010	1.088	1.165
.95	.0196	.0393	.0589	.0785	.1570	.2355	.3141	.3926	.4711	.550	.628	.707	.785	.864	.942	1.021	1.099	1.178
.96	.0198	.0397	.0595	.0793	.1587	.2380	.3174	.3967	.4760	.555	.635	.714	.793	.873	.952	1.031	1.111	1.190
.97	.0200	.0401	.0601	.0802	.1603	.2405	.3207	.4008	.4810	.561	.641	.721	.802	.882	.962	1.042	1.122	1.202
.98	.0203	.0405	.0607	.0810	.1620	.2430	.3240	.4050	.4860	.567	.648	.729	.810	.891	.972	1.053	1.134	1.215
.99	.0205	.0409	.0614	.0818	.1636	.2455	.3273	.4091	.4909	.573	.655	.736	.818	.900	.982	1.064	1.145	1.227
1.00	.0207	.0413	.0620	.0826	.1653	.2479	.3306	.4132	.4959	.579	.661	.744	.826	.909	.992	1.074	1.157	1.240

Table 4.—Acre-feet equivalent to a given number of second-feet flowing for a given length of time. (See sec. 3.)—Continued

Second-feet	Hours 16	Hours 17	Hours 18	Hours 19	Hours 20	Hours 21	Hours 22	Hours 23	Hours 24	Days of 24 hours 2	Days of 24 hours 3	Days of 24 hours 4	Days of 24 hours 5	Days of 24 hours 6	Days of 24 hours 7	Days of 24 hours 8	Days of 24 hours 9	Days of 24 hours 10
0.71	0.94	1.00	1.06	1.11	1.17	1.23	1.29	1.35	1.41	2.82	4.22	5.63	7.04	8.45	9.86	11.27	12.67	14.08
.72	.95	1.01	1.07	1.13	1.19	1.25	1.31	1.37	1.43	2.86	4.28	5.71	7.14	8.57	10.00	11.42	12.85	14.28
.73	.97	1.03	1.09	1.14	1.21	1.27	1.33	1.39	1.45	2.90	4.34	5.79	7.24	8.69	10.14	11.58	13.03	14.48
.74	.98	1.04	1.10	1.16	1.22	1.28	1.35	1.41	1.47	2.94	4.40	5.87	7.34	8.81	10.27	11.74	13.21	14.68
.75	.99	1.05	1.12	1.18	1.24	1.30	1.36	1.43	1.49	2.98	4.46	5.95	7.44	8.93	10.41	11.90	13.39	14.88
.76	1.00	1.07	1.13	1.19	1.26	1.31	1.38	1.44	1.51	3.01	4.52	6.03	7.54	9.04	10.55	12.06	13.57	15.07
.77	1.02	1.08	1.15	1.21	1.27	1.34	1.40	1.46	1.53	3.05	4.58	6.11	7.64	9.16	10.69	12.22	13.75	15.27
.78	1.03	1.10	1.16	1.22	1.29	1.35	1.42	1.48	1.55	3.09	4.64	6.19	7.74	9.28	10.83	12.38	13.92	15.47
.79	1.04	1.11	1.18	1.24	1.31	1.37	1.44	1.50	1.57	3.13	4.70	6.27	7.83	9.40	10.97	12.54	14.10	15.67
.80	1.06	1.12	1.19	1.26	1.32	1.39	1.45	1.52	1.59	3.17	4.76	6.35	7.93	9.52	11.11	12.70	14.28	15.87
.81	1.07	1.14	1.20	1.27	1.34	1.41	1.47	1.54	1.61	3.21	4.82	6.43	8.03	9.64	11.25	12.85	14.46	16.07
.82	1.08	1.15	1.22	1.29	1.36	1.43	1.49	1.56	1.63	3.25	4.88	6.51	8.13	9.76	11.39	13.01	14.64	16.26
.83	1.10	1.17	1.23	1.30	1.37	1.44	1.51	1.58	1.65	3.29	4.94	6.59	8.23	9.88	11.52	13.17	14.82	16.46
.84	1.11	1.18	1.25	1.32	1.39	1.46	1.53	1.60	1.67	3.33	5.00	6.66	8.33	10.00	11.66	13.33	15.00	16.66
.85	1.12	1.19	1.26	1.33	1.40	1.48	1.55	1.62	1.69	3.37	5.06	6.74	8.43	10.12	11.80	13.49	15.17	16.86
.86	1.14	1.21	1.28	1.35	1.42	1.49	1.56	1.63	1.71	3.41	5.12	6.82	8.53	10.23	11.94	13.65	15.35	17.06
.87	1.15	1.22	1.29	1.37	1.44	1.51	1.58	1.65	1.73	3.45	5.18	6.90	8.63	10.35	12.08	13.80	15.53	17.26
.88	1.16	1.24	1.31	1.38	1.45	1.53	1.60	1.67	1.75	3.50	5.24	6.98	8.73	10.47	12.22	13.96	15.71	17.45
.89	1.17	1.25	1.32	1.40	1.47	1.54	1.62	1.69	1.77	3.53	5.30	7.06	8.83	10.59	12.36	14.12	15.89	17.65
.90	1.19	1.26	1.34	1.41	1.49	1.56	1.64	1.71	1.79	3.57	5.36	7.14	8.93	10.71	12.50	14.28	16.07	17.85
.91	1.20	1.28	1.35	1.43	1.50	1.58	1.65	1.73	1.80	3.61	5.41	7.22	9.02	10.83	12.63	14.44	16.24	18.05
.92	1.22	1.29	1.37	1.44	1.52	1.60	1.67	1.75	1.82	3.65	5.47	7.30	9.12	10.95	12.77	14.60	16.43	18.25
.93	1.23	1.31	1.38	1.46	1.54	1.61	1.69	1.77	1.84	3.69	5.53	7.38	9.22	11.07	12.91	14.76	16.60	18.45
.94	1.24	1.32	1.40	1.48	1.55	1.63	1.71	1.79	1.86	3.73	5.59	7.46	9.32	11.19	13.05	14.93	16.88	18.64
.95	1.26	1.33	1.41	1.50	1.57	1.65	1.73	1.81	1.88	3.77	5.65	7.54	9.42	11.31	13.19	15.07	16.96	18.84
.96	1.27	1.35	1.43	1.51	1.59	1.67	1.75	1.82	1.90	3.81	5.71	7.62	9.52	11.42	13.33	15.23	17.14	19.04
.97	1.28	1.36	1.44	1.52	1.60	1.68	1.76	1.84	1.92	3.85	5.77	7.70	9.62	11.54	13.47	15.39	17.32	19.24
.98	1.30	1.38	1.46	1.54	1.62	1.70	1.78	1.86	1.94	3.89	5.83	7.78	9.72	11.66	13.61	15.55	17.49	19.44
.99	1.31	1.40	1.47	1.55	1.64	1.72	1.80	1.88	1.96	3.93	5.89	7.85	9.82	11.78	13.74	15.71	17.67	19.64
1.00	1.32	1.41	1.49	1.57	1.65	1.74	1.82	1.90	1.98	3.97	5.95	7.93	9.92	11.90	13.88	15.87	17.85	19.83

Table No. 100. RELATIVE VELOCITY AND DISCHARGE FOR VARIOUS DEPTHS OF FLOW—CIRCULAR CONDUITS (Folwell)

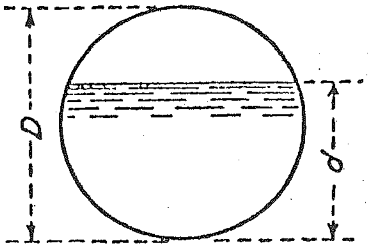
d Depth		p Wetted Perimeter	a Area of Flow	R Hydraulic Radius	$2\sqrt{R}$	By Kutter's Formula: Corrected Proportional Velocities	By Kutter's Formula: Corrected Proportional Discharge
Full	1.0	3.142	0.7854	0.25	1.00	1.00	1.000
	0.95	2.691	0.7708	0.286	1.07	1.11	1.068
	0.9	2.498	0.7445	0.298	1.09	1.15	1.073
	0.8	2.214	0.6735	0.304	1.10	1.16	0.98
	0.7	1.983	0.5874	0.296	1.08	1.14	0.84
	0.6	1.772	0.4920	0.278	1.05	1.08	0.67
Half	0.5	1.571	0.3927	0.250	1.00	1.00	0.50
	0.4	1.369	0.2934	0.214	0.93	0.88	0.33
	0.3	1.159	0.1981	0.171	0.83	0.72	0.19
	0.25	1.047	0.1536	0.146	0.76	0.65	0.14
	0.2	0.927	0.1118	0.121	0.69	0.56	0.09
	0.1	0.643	0.0408	0.0635	0.50	0.36	0.03
Empty	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table No. 101. AREA, WETTED PERIMETER, AND HYDRAULIC RADIUS OF PARTIALLY FILLED CIRCULAR CONDUIT SECTIONS

$\frac{d}{D}$	$\frac{\text{area}}{D^2}$	$\frac{\text{wet. per.}}{D}$	$\frac{\text{hyd. rad.}}{D}$	$\frac{d}{D}$	$\frac{\text{area}}{D^2}$	$\frac{\text{wet. per.}}{D}$	$\frac{\text{hyd. rad.}}{D}$
0.01	0.0013	0.2003	0.0066	0.51	0.4027	1.5908	0.2531
0.02	0.0037	0.2838	0.0132	0.52	0.4127	1.6108	0.2561
0.03	0.0069	0.3482	0.0197	0.53	0.4227	1.6308	0.2591
0.04	0.0105	0.4027	0.0262	0.54	0.4327	1.6509	0.2620
0.05	0.0147	0.4510	0.0326	0.55	0.4426	1.6710	0.2649
0.06	0.0192	0.4949	0.0389	0.56	0.4526	1.6911	0.2676
0.07	0.0242	0.5355	0.0451	0.57	0.4625	1.7113	0.2703
0.08	0.0294	0.5735	0.0513	0.58	0.4723	1.7315	0.2728
0.09	0.0350	0.6094	0.0574	0.59	0.4822	1.7518	0.2753
0.10	0.0409	0.6435	0.0635	0.60	0.4920	1.7722	0.2776
0.11	0.0470	0.6761	0.0695	0.61	0.5018	1.7926	0.2797
0.12	0.0534	0.7075	0.0754	0.62	0.5115	1.8132	0.2818
0.13	0.0600	0.7377	0.0813	0.63	0.5212	1.8338	0.2839
0.14	0.0668	0.7670	0.0871	0.64	0.5308	1.8546	0.2860
0.15	0.0739	0.7954	0.0929	0.65	0.5404	1.8755	0.2881
0.16	0.0811	0.8230	0.0986	0.66	0.5499	1.8965	0.2899
0.17	0.0885	0.8500	0.1042	0.67	0.5594	1.9177	0.2917
0.18	0.0961	0.8763	0.1097	0.68	0.5687	1.9391	0.2935
0.19	0.1039	0.9020	0.1152	0.69	0.5780	1.9606	0.2950
0.20	0.1118	0.9273	0.1206	0.70	0.5872	1.9823	0.2962
0.21	0.1199	0.9521	0.1259	0.71	0.5964	2.0042	0.2973
0.22	0.1281	0.9764	0.1312	0.72	0.6054	2.0264	0.2984
0.23	0.1365	1.0003	0.1364	0.73	0.6143	2.0488	0.2995
0.24	0.1449	1.0239	0.1416	0.74	0.6231	2.0714	0.3006
0.25	0.1535	1.0472	0.1466	0.75	0.6318	2.0944	0.3017
0.26	0.1623	1.0701	0.1516	0.76	0.6404	2.1176	0.3025
0.27	0.1711	1.0928	0.1566	0.77	0.6489	2.1412	0.3032
0.28	0.1800	1.1152	0.1614	0.78	0.6573	2.1652	0.3037
0.29	0.1890	1.1373	0.1662	0.79	0.6655	2.1895	0.3040
0.30	0.1982	1.1593	0.1709	0.80	0.6736	2.2143	0.3042
0.31	0.2074	1.1810	0.1755	0.81	0.6815	2.2395	0.3044
0.32	0.2167	1.2025	0.1801	0.82	0.6893	2.2653	0.3043
0.33	0.2260	1.2239	0.1848	0.83	0.6969	2.2916	0.3041
0.34	0.2355	1.2451	0.1891	0.84	0.7043	2.3186	0.3038
0.35	0.2450	1.2661	0.1935	0.85	0.7115	2.3462	0.3033
0.36	0.2546	1.2870	0.1978	0.86	0.7186	2.3746	0.3026
0.37	0.2642	1.3078	0.2020	0.87	0.7254	2.4038	0.3017
0.38	0.2739	1.3284	0.2061	0.88	0.7320	2.4341	0.3008
0.39	0.2836	1.3490	0.2102	0.89	0.7384	2.4655	0.2996
0.40	0.2934	1.3694	0.2142	0.90	0.7445	2.4981	0.2980
0.41	0.3032	1.3898	0.2181	0.91	0.7504	2.5322	0.2963
0.42	0.3130	1.4101	0.2220	0.92	0.7560	2.5681	0.2944
0.43	0.3229	1.4303	0.2257	0.93	0.7642	2.6061	0.2922
0.44	0.3328	1.4505	0.2294	0.94	0.7662	2.6467	0.2896
0.45	0.3428	1.4706	0.2331	0.95	0.7707	2.6906	0.2864
0.46	0.3527	1.4907	0.2366	0.96	0.7749	2.7389	0.2830
0.47	0.3627	1.5108	0.2400	0.97	0.7785	2.7934	0.2787
0.48	0.3727	1.5308	0.2434	0.98	0.7816	2.8578	0.2735
0.49	0.3827	1.5508	0.2467	0.99	0.7841	2.9412	0.2665
0.50	0.3927	1.5708	0.2500	1.00	0.7854	3.1416	0.2500

Table No. 102. VELOCITY HEAD AND DISCHARGE AT CRITICAL DEPTHS AND STATIC PRESSURES IN CIRCULAR CONDUITS PARTLY FULL

D = Diameter of circle.
d = Depth of water.
h_v = Velocity head for a critical depth of d.
Q = Discharge when the critical depth is d.
P = Pressure on cross section of water prism in cubic units of water. To get P in pounds, when d and D are in feet, multiply by 62.5.



$\frac{d}{D}$	$\frac{h_v}{D}$	$\frac{Q}{D^{5/2}}$	$\frac{P}{D^3}$	$\frac{d}{D}$	$\frac{h_v}{D}$	$\frac{Q}{D^{5/2}}$	$\frac{P}{D^3}$	$\frac{d}{D}$	$\frac{h_v}{D}$	$\frac{Q}{D^{5/2}}$	$\frac{P}{D^3}$
1	2	3	4	1	2	3	4	1	2	3	4
.01	.0033	.0006	.0000	.34	.1243	.6657	.0332	.67	.2974	2.4464	.1644
.02	.0067	.0025	.0000	.35	.1284	.7040	.0356	.68	.3048	2.5182	.1700
.03	.0101	.0055	.0001	.36	.1326	.7433	.0381	.69	.3125	2.5912	.1758
.04	.0134	.0098	.0002	.37	.1368	.7836	.0407	.70	.3204	2.6656	.1816
.05	.0168	.0153	.0003	.38	.1411	.8249	.0434	.71	.3286	2.7414	.1875
.06	.0203	.0220	.0005	.39	.1454	.8671	.0462	.72	.3371	2.8188	.1935
.07	.0237	.0298	.0007	.40	.1497	.9103	.0491	.73	.3459	2.8977	.1996
.08	.0271	.0389	.0010	.41	.1541	.9545	.0520	.74	.3552	2.9783	.2058
.09	.0306	.0491	.0013	.42	.1586	.9996	.0551	.75	.3648	3.0607	.2121
.10	.0341	.0605	.0017	.43	.1631	1.0458	.0583	.76	.3749	3.1450	.2185
.11	.0376	.0731	.0021	.44	.1676	1.0929	.0616	.77	.3855	3.2314	.2249
.12	.0411	.0868	.0026	.45	.1723	1.1410	.0650	.78	.3967	3.3200	.2314
.13	.0446	.1016	.0032	.46	.1769	1.1899	.0684	.79	.4085	3.4112	.2380
.14	.0482	.1176	.0038	.47	.1817	1.2399	.0720	.80	.4210	3.5050	.2447
.15	.0517	.1347	.0045	.48	.1865	1.2908	.0757	.81	.4343	3.6019	.2515
.16	.0553	.1530	.0053	.49	.1914	1.3427	.0795	.82	.4485	3.7021	.2584
.17	.0589	.1724	.0061	.50	.1964	1.3955	.0833	.83	.4638	3.8061	.2653
.18	.0626	.1928	.0070	.51	.2014	1.4493	.0873	.84	.4803	3.9144	.2723
.19	.0662	.2144	.0080	.52	.2065	1.5041	.0914	.85	.4982	4.0276	.2794
.20	.0699	.2371	.0091	.53	.2117	1.5598	.0956	.86	.5177	4.1465	.2865
.21	.0736	.2609	.0103	.54	.2170	1.6164	.0998	.87	.5392	4.2721	.2938
.22	.0773	.2857	.0115	.55	.2224	1.6735	.1042	.88	.5632	4.4056	.3011
.23	.0811	.3116	.0128	.56	.2279	1.7327	.1087	.89	.5900	4.5486	.3084
.24	.0848	.3386	.0143	.57	.2335	1.7923	.1133	.90	.6204	4.7033	.3158
.25	.0887	.3667	.0157	.58	.2393	1.8530	.1179	.91	.6555	4.8725	.3233
.26	.0925	[illegible]	.0173	.59	.2451	1.9146	.1227	.92	.6966	5.0603	.3308
.27	.0963	[illegible]	.0190	.60	.2511	1.9773	.1276	.93	.7459	5.2726	.3384
.28	.1002	[illegible]	.0207	.61	.2572	2.0409	.1326	.94	.8065	5.5183	.3460
.29	.1042	[illegible]	.0226	.62	.2635	2.1057	.1376	.95	.8841	5.8118	.3537
.30	.1081	[illegible]	.0255	.63	.2699	2.1716	.1428	.96	.9885	6.1787	.3615
.31	.1121	[illegible]	.0266	.64	.2765	2.2386	.1481	.97	1.1410	6.6692	.3692
.32	.1161	[illegible]	.0287	.65	.2833	2.3067	.1534	.98	1.3958	7.4063	.3770
.33	.1202	[illegible]	.0309	.66	.2902	2.3760	.1589	.99	1.9700	8.8263	.3848
								1.00	....	....	.3927

Table No. 146. PIPE AREA AND CONTENTS

Contents in cubic feet, U. S. gallons and weight of water per foot of length for pipe of various diameters, also area in square feet and inches, and circumferences in inches.

Dia. of Pipe in In.	Area in Sq. Ft. or Contents in Cu. Ft. per Ft. of Length	Contents in U. S. Gallons per Ft. Length	Weight of Water in One Foot of Length in Lbs.	Area in Sq. In.	Circumference in In.
1	.0055	.0408	.34	.78	3.14
2	.0218	.1632	1.36	3.14	6.28
3	.0491	.3672	3.06	7.06	9.42
4	.0873	.6528	5.44	12.56	12.56
5	.1364	1.020	8.51	19.63	15.70
6	.1963	1.469	12.25	28.27	18.85
7	.2673	1.999	16.68	38.48	21.99
8	.3491	2.611	21.79	50.26	25.13
9	.4418	3.305	27.57	63.61	28.27
10	.5454	4.08	34.04	78.54	31.41
11	.66	4.937	41.19	95.03	34.55
12	.7854	5.875	49.02	113.10	37.69
13	.9218	6.895	57.54	132.73	40.84
14	1.069	7.997	66.73	153.94	43.98
15	1.227	9.180	76.60	176.71	47.12
16	1.396	10.44	87.16	201.06	50.26
18	1.768	13.22	110.31	254.47	56.54
20	2.182	16.32	136.19	314.16	62.83
22	2.640	19.75	164.79	380.13	69.11
24	3.142	23.50	196.11	452.39	75.39
26	3.687	27.58	230.16	530.93	81.68
28	4.276	31.99	266.93	615.75	87.96
30	4.909	36.72	306.42	706.86	94.24
32	5.585	41.78	348.64	804.25	100.53
34	6.305	47.16	393.59	907.92	106.81
36	7.069	52.88	441.25	1017.9	113.09
38	7.876	58.92	491.64	1134.1	119.38
40	8.727	65.28	544.76	1256.6	125.66
42	9.621	71.97	600.59	1385.4	131.94
44	10.559	78.99	659.16	1520.5	138.23
46	11.541	86.33	720.44	1661.9	144.51
48	12.566	94.00	784.45	1809.6	150.79
50	13.635	102.00	851.18	1963.5	157.08
52	14.748	110.32	920.64	2123.7	163.36
54	15.90	118.97	992.82	2290.2	169.64
60	19.63	146.88	1225.71	2827.4	188.49
66	23.76	177.72	1483.11	3421.2	207.34
72	28.27	211.51	1765.02	4071.5	226.19
78	33.18	248.23	2071.42	4778.3	245.04
84	38.48	287.88	2402.36	5541.7	263.89
90	44.18	330.48	2757.81	6361.7	282.74
96	50.27	376.01	3137.78	7238.2	301.59

Table No. 103. NET SAFE LOADS FOR WOOD BEAMS

Supported at both ends and uniformly loaded. For concentrated load in center of span use one-half of Tabular Value. For uniformly distributed load on beam fixed at one end (cantilever) use one-quarter of Tabular Value.

For concentrated load at end of cantilever use one-eighth of Tabular Value.

Nominal Size	Actual Size	Factor	Span in Feet 4	6	8	10	12	14	16	18	20	22	24	26
2x4	1⅝x 3⅝	1.50	885	585	......	......	......	......	......	......	......	......	......	......
2x6	1⅝x 5⅝	1.40	2134	1416	1052	833	......	......	......	......	......	......	......	......
2x8	1⅝x 7½	1.40	......	2519	1878	1491	1230	1043	......	......	......	......	......	......
2x10	1⅝x 9½	1.36	......	......	3024	2404	1990	1689	1464	1286	......	......	......	......
2x12	1⅝x11½	1.34	......	......	4440	3535	2928	2490	2162	1902	1692	......	......	......
3x6	2½x 5½	1.43	3135	2078	1546	1224	......	......	......	......	......	......	......	......
3x8	2½x 7½	1.37	......	3875	2888	2294	1893	1605	......	......	......	......	......	......
3x10	2½x 9½	1.33	......	......	4651	3699	3059	2599	2251	1977	......	......	......	......
3x12	2½x11½	1.31	......	......	6826	5432	4501	3829	3325	2925	2604	......	......	......
3x14	2½x13½	1.29	......	......	......	7501	6222	5301	4600	4057	3619	3256	......	......
3x16	2½x15½	1.28	......	......	......	......	8220	7011	6094	5380	4805	4328	......	......
4x4	3½x 3½	1.49	1775	1174	......	......	......	......	......	......	......	......	......	......
4x6	3½x 5½	1.36	4390	2910	2164	1713	......	......	......	......	......	......	......	......
4x8	3½x 7½	1.30	......	5430	4048	3213	2652	2248	......	......	......	......	......	......
4x10	3½x 9½	1.27	......	......	6515	5179	4286	3641	3151	2769	......	......	......	......
4x12	3½x11½	1.25	......	......	9556	7604	6299	5361	4650	4096	3645	......	......	......
4x14	3½x13½	1.23	......	......	......	10504	8708	7418	6446	5685	5064	4558	......	......
4x16	3½x15½	1.22	......	......	......	......	11510	9817	8531	7529	6722	6059	......	......
6x6	5½x 5½	1.30	6903	4577	3403	2694	......	......	......	......	......	......	......	......
6x8	5½x 7½	1.24	......	8524	6357	5044	4164	3528	......	......	......	......	......	......
6x10	5½x 9½	1.21	......	......	10230	8133	6726	5716	4950	4345	......	......	......	......
6x12	5½x11½	1.19	......	......	15032	11956	9907	8426	7311	6437	5728	......	......	......

Values in the table are based on surfaced sizes and a unit stress of 1500 pounds per square inch. Maximum horizontal shear does not exceed 185 pounds per square inch. To obtain the net safe loads for rough sizes, multiply Tabular Values by the factor given for the beam in question. The safe loads given are net, the weight of the beam having been deducted. Deflections do not exceed 1/32 inch per foot of span for loads in bold face type. Modulus of elasticity used—1,643,000 pounds per square inch.

Table No. 104. SAFE BEARING LOADS IN THOUSANDS OF POUNDS FOR SQUARE END COLUMNS SYMMETRICALLY LOADED

Based on Formula by the U. S. Department of Agriculture—Forest Service

Nominal Size	Actual Size	Length of Column in Feet 6	8	10	12	14	16	18	20	22	24
4x 4	3½x 3½	10350	8800	......	......	......	......	......	......	......	......
	4 x 4	14380	12450	......	......	......	......	......	......	......	......
6x 6	5½x 5½	36300	27520	24760	22280	20080	......	......	......	......	......
	6 x 6	43200	33850	30700	27850	25300	......	......	......	......	......
8x 8	7½x 7½	......	67500	53050	49180	45430	41990	38880	......	......	......
	8 x 8	......	76950	62070	57540	53610	49550	46270	......	......	......
10x10	9½x 9½	......	108300	108300	86750	81550	76790	72350	67910	......	......
	10 x10	......	120210	120210	98030	92150	87540	82480	77420	......	......
12x12	11½x11½	......	158700	158700	158700	158700	122520	116480	110620	105220	100140
	12 x12	......	172980	172980	172980	172980	136000	129290	122790	117850	112160
14x14	13½x13½	......	218700	218700	218700	218700	218700	171680	164240	157460	150900
	14 x14	......	236200	236200	236200	236200	236200	187130	180660	173210	166000

Values in the table are given for both surfaced and full size rough timbers.

Fiber stress in end compression taken at 1200 pounds per square inch.

Working unit Stress $= C \dfrac{(700+15r)}{(700+15r+r^2)}$ where $r = \dfrac{L}{D}$ and

C = Safe fiber stress in end compression in pounds per square inch.

L = Length of column in inches.

D = Least side or diameter in inches.

When $\dfrac{L}{D}$ is less than 15, C is used.

Table No. 103. CONTENTS OF LUMBER

Table shows the number of board feet in various sizes, for lengths given

Size of Piece, Inches	Length of Piece in Feet							
	10	12	14	16	18	20	22	24
1x 4	3⅓	4	4⅔	5⅓	6	6⅔	7⅓	8
1x 6	5	6	7	8	9	10	11	12
1x 8	6⅔	8	9⅓	10⅔	12	13⅓	14⅔	16
1x10	8⅓	10	11⅔	13⅓	15	16⅔	18⅓	20
1x12	10	12	14	16	18	20	22	24
1x14	11⅔	14	16⅓	18⅔	21	23⅓	25⅔	28
1x16	13⅓	16	18⅔	21⅓	24	26⅔	29⅓	32
1x18	15	18	21	24	27	30	33	36
1x20	16⅔	20	23⅓	26⅔	30	33⅓	36⅔	40
1x24	20	24	28	32	36	40	44	48
2x 4	6⅔	8	9⅓	10⅔	12	13⅓	14⅔	16
2x 6	10	12	14	16	18	20	22	24
2x 8	13⅓	16	18⅔	21⅓	24	26⅔	29⅓	32
2x10	16⅔	20	23⅓	26⅔	30	33⅓	36⅔	40
2x12	20	24	28	32	36	40	44	48
2x14	23⅓	28	32⅔	37⅓	42	46⅔	51⅓	56
2x16	26⅔	32	37⅓	42⅔	48	53⅓	58⅔	64
3x 6	15	18	21	24	27	30	33	36
3x 8	20	24	28	32	36	40	44	48
3x10	25	30	35	40	45	50	55	60
3x12	30	36	42	48	54	60	66	72
3x14	35	42	49	56	63	70	77	84
3x16	40	48	56	64	72	80	88	96
4x 4	13⅓	16	18⅔	21⅓	24	26⅔	29⅓	32
4x 6	20	24	28	32	36	40	44	48
4x 8	26⅔	32	37⅓	42⅔	48	53⅓	58⅔	64
4x10	33⅓	40	46⅔	53⅓	60	66⅔	73⅓	80
4x12	40	48	56	64	72	80	88	96
4x14	46⅔	56	65⅓	74⅔	84	93⅓	102⅔	112
4x16	53⅓	64	74⅔	85⅓	96	106⅔	117⅓	128
6x 6	30	36	42	48	54	60	66	72
6x 8	40	48	56	64	72	80	88	96
6x10	50	60	70	80	90	100	110	120
6x12	60	72	84	96	108	120	132	144
6x14	70	84	98	112	126	140	154	168
6x16	80	96	112	128	144	160	176	192
6x18	90	108	126	144	162	180	198	216
6x20	100	120	140	160	180	200	220	240
8x 8	53⅓	64	74⅔	85⅓	96	106⅔	117⅓	128
8x10	66⅔	80	93⅓	106⅔	120	133⅓	146⅔	160
8x12	80	96	112	128	144	160	176	192
8x14	93⅓	112	130⅔	149⅓	168	186⅔	205⅓	224
10x10	83⅓	100	116⅔	133⅓	150	166⅔	183⅓	200
10x12	100	120	140	160	180	200	220	240
10x14	116⅔	140	163⅓	186⅔	210	233⅓	256⅔	280
10x16	133⅓	160	186⅔	213⅓	240	266⅔	293⅓	320
12x12	120	144	168	192	216	240	264	288
12x14	140	168	196	224	252	280	308	336
12x16	160	192	224	256	288	320	352	384
14x14	163⅓	196	228⅔	261⅓	294	326⅔	359⅓	392
14x16	186⅔	224	261⅓	298⅔	336	373⅓	410⅔	448

Table No. 109. CAPACITY OF RECTANGULAR TANKS IN U. S. GALLONS, PER FOOT OF HEIGHT

Width of Tank	2′	2′ 6″	3′	3′ 6″	4′	4′ 6″	5′	5′ 6″	6′	6′ 6″	7′	8′	9′	10′	11′	12′
	LENGTH OF TANK															
2′ 0″	29.92	37.40	44.88	52.36	59.84	67.32	74.81	82.29	89.77	97.25	104.73	119.69	134.65	149.61	164.57	179.53
2′ 6″	....	46.75	56.10	65.45	74.80	84.16	93.51	102.86	112.21	121.56	130.91	149.61	168.31	187.01	205.71	224.41
3′ 0″	....	....	67.32	78.54	89.77	100.99	112.21	123.43	134.65	145.87	157.09	179.53	202.97	224.41	246.86	269.30
3′ 6″	....	....	....	91.64	104.73	117.82	130.91	144.00	157.09	170.18	183.27	209.45	235.63	261.82	288.00	314.18
4′ 0″	....	....	....	....	119.69	134.65	149.61	164.57	179.53	194.49	209.45	239.37	269.30	299.22	329.14	359.06
4′ 6″	....	....	....	....	....	151.48	168.31	185.14	201.97	218.80	235.63	269.30	302.96	336.62	370.28	403.94
5′ 0″	....	....	....	....	....	....	187.01	205.71	224.41	243.11	261.82	299.22	336.62	374.03	411.43	448.83
5′ 6″	....	....	....	....	....	....	....	226.28	246.86	267.43	288.00	329.14	370.28	411.43	452.57	493.71
6′ 0″	....	....	....	....	....	....	....	....	269.30	291.74	314.18	359.06	403.94	448.83	493.71	538.59
6′ 6″	....	....	....	....	....	....	....	....	....	316.05	340.36	388.98	437.60	486.23	534.85	583.47
7′ 0″	....	....	....	....	....	....	....	....	....	....	366.54	418.91	471.27	523.64	575.99	628.36
7′ 6″	....	....	....	....	....	....	....	....	....	....	....	448.83	504.93	561.04	617.14	673.24
8′ 0″	....	....	....	....	....	....	....	....	....	....	....	478.75	538.59	598.44	658.28	718.12
8′ 6″	....	....	....	....	....	....	....	....	....	....	....	....	572.25	635.84	699.42	763.00
9′ 0″	....	....	....	....	....	....	....	....	....	....	....	....	605.92	673.25	740.56	807.89
9′ 6″	....	....	....	....	....	....	....	....	....	....	....	....	....	710.65	781.71	852.77
10′ 0″	....	....	....	....	....	....	....	....	....	....	....	....	....	748.05	822.86	897.66
10′ 6″	....	....	....	....	....	....	....	....	....	....	....	....	....	....	864.00	942.56
11′ 0″	....	....	....	....	....	....	....	....	....	....	....	....	....	....	905.14	987.43
11′ 6″	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1032.3
12′ 0″	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1077.2

Table No. 108. CAPACITY OF VERTICAL CYLINDRICAL TANKS IN U. S. GALLONS, PER FOOT OF HEIGHT

Diameter Ft.	Diameter Ins.	Gals. per ft. depth	Diameter Ft.	Diameter Ins.	Gals. per ft. depth	Diameter Ft.	Diameter Ins.	Gals. per ft. depth	Diameter Ft.	Diameter Ins.	Gals. per ft. depth
1	0	5.87	4	6	118.97	12	0	846.03	22	6	2974.3
1	1	6.89	4	7	123.42	12	3	881.65	22	9	3040.8
1	2	8.00	4	8	127.95	12	6	918.00	23	0	3108.0
1	3	9.18	4	9	132.56	12	9	955.00	23	3	3175.9
1	4	10.44	4	10	137.25	13	0	992.91	23	6	3244.6
1	5	11.79	4	11	142.02	13	3	1031.5	23	9	3314.0
1	6	13.22	5	0	146.88	13	6	1070.8	24	0	3384.1
1	7	14.73	5	1	151.82	13	9	1110.8	24	3	3455.0
1	8	16.32	5	2	156.83	14	0	1151.5	24	6	3526.6
1	9	17.99	5	3	161.93	14	3	1193.0	24	9	3598.9
1	10	19.75	5	4	167.12	14	6	1235.3	25	0	3672.0
1	11	21.58	5	5	172.38	14	9	1278.2	25	3	3745.8
2	0	23.50	5	6	177.72	15	0	1321.9	25	6	3820.3
2	1	25.50	5	7	183.15	15	3	1366.4	25	9	3895.6
2	2	27.58	5	8	188.66	15	6	1411.5	26	0	3971.6
2	3	29.74	5	9	194.25	15	9	1457.4	26	3	4048.4
2	4	31.99	5	10	199.92	16	0	1504.1	26	6	4125.9
2	5	34.31	5	11	205.67	16	3	1551.4	26	9	4204.1
2	6	36.72	6	0	211.51	16	6	1599.5	27	0	4283.0
2	7	39.21	6	3	229.50	16	9	1648.4	27	3	4362.7
2	8	41.78	6	6	248.23	17	0	1697.9	27	6	4443.1
2	9	44.43	6	9	267.69	17	3	1748.2	27	9	4524.3
2	10	47.16	7	0	287.88	17	6	1799.3	28	0	4606.2
2	11	49.98	7	3	308.81	17	9	1851.1	28	3	4688.8
3	0	52.88	7	6	330.48	18	0	1903.6	28	6	4772.1
3	1	55.86	7	9	352.88	18	3	1956.8	28	9	4856.2
3	2	58.92	8	0	376.01	18	6	2010.8	29	0	4941.0
3	3	62.06	8	3	399.88	18	9	2065.5	29	3	5026.6
3	4	65.28	8	6	424.48	19	0	2120.9	29	6	5112.9
3	5	68.58	8	9	449.82	19	3	2177.1	29	9	5199.9
3	6	71.97	9	0	475.89	19	6	2234.0	30	0	5287.7
3	7	75.44	9	3	502.70	19	9	2291.7	30	3	5376.2
3	8	78.99	9	6	530.24	20	0	2350.1	30	6	5465.4
3	9	82.62	9	9	558.51	20	3	2409.2	30	9	5555.4
3	10	86.33	10	0	587.52	20	6	2469.1	31	0	5646.1
3	11	90.13	10	3	617.26	20	9	2529.6	31	3	5737.5
4	0	94.00	10	6	647.74	21	0	2591.0	31	6	5829.7
4	1	97.96	10	9	678.95	21	3	2653.0	31	9	5922.6
4	2	102.00	11	0	710.90	21	6	2715.8	32	0	6016.2
4	3	106.12	11	3	743.58	21	9	2779.3	32	3	6110.6
4	4	110.32	11	6	776.99	22	0	2843.6	32	6	6205.7
4	5	114.61	11	9	811.14	22	3	2908.6	32	9	6301.5

FIGURE 15. Reduction of Water Yield Increase with Vegetative Recovery.

Graphs are based on the following Assumptions:
Vegetative recovery or recovery of evapotransporation, interception and decreasing redistribution proceeds logarithmically. (From Ziemer, Kovner, Rothacher, Haupt).

The average increase to soil moisture from logging, ie; due to clearcuts or harvesting etc. is about 6 inches of water.

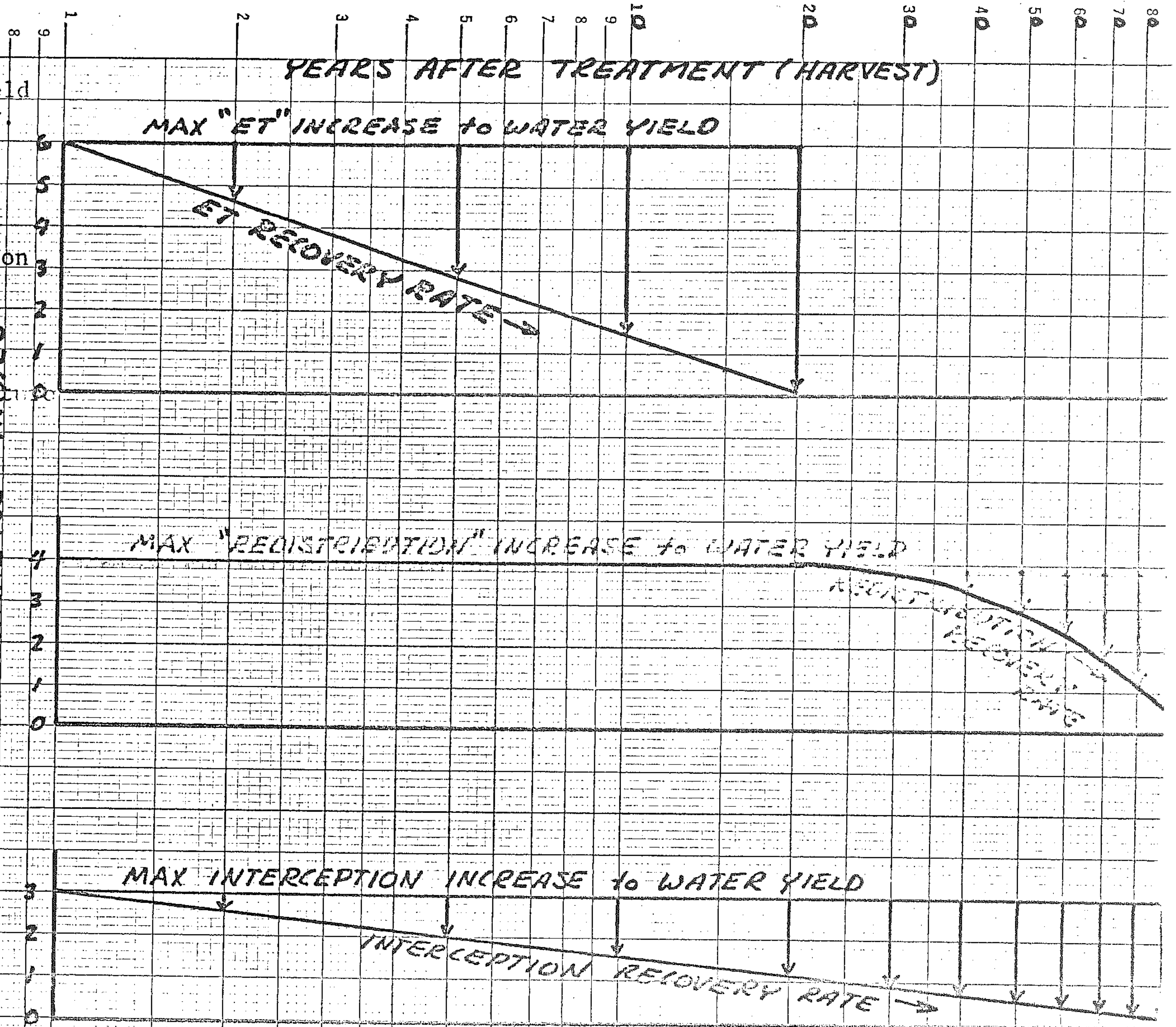
Teh average gain of moisture due to a decrease in the interception factor is about 3 inches.

The average gain in moisture due to redistribution of snow is about 4 inches.

Average recocery period to full ET loss is about 20 years.

Average recovery period to full Interception loss is about 100 years.

Average recovery period of the redistribution factor is about 100 years.



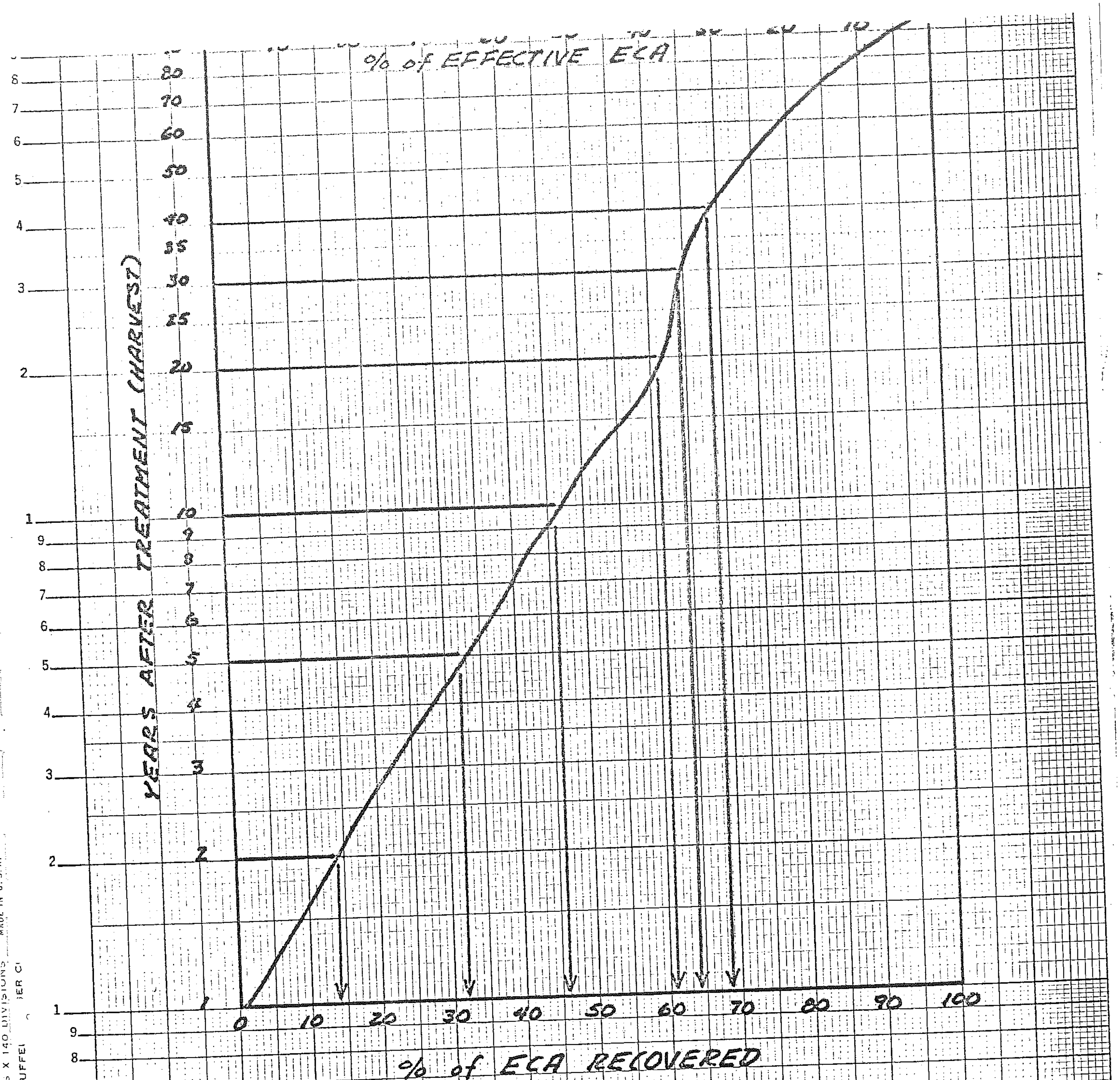
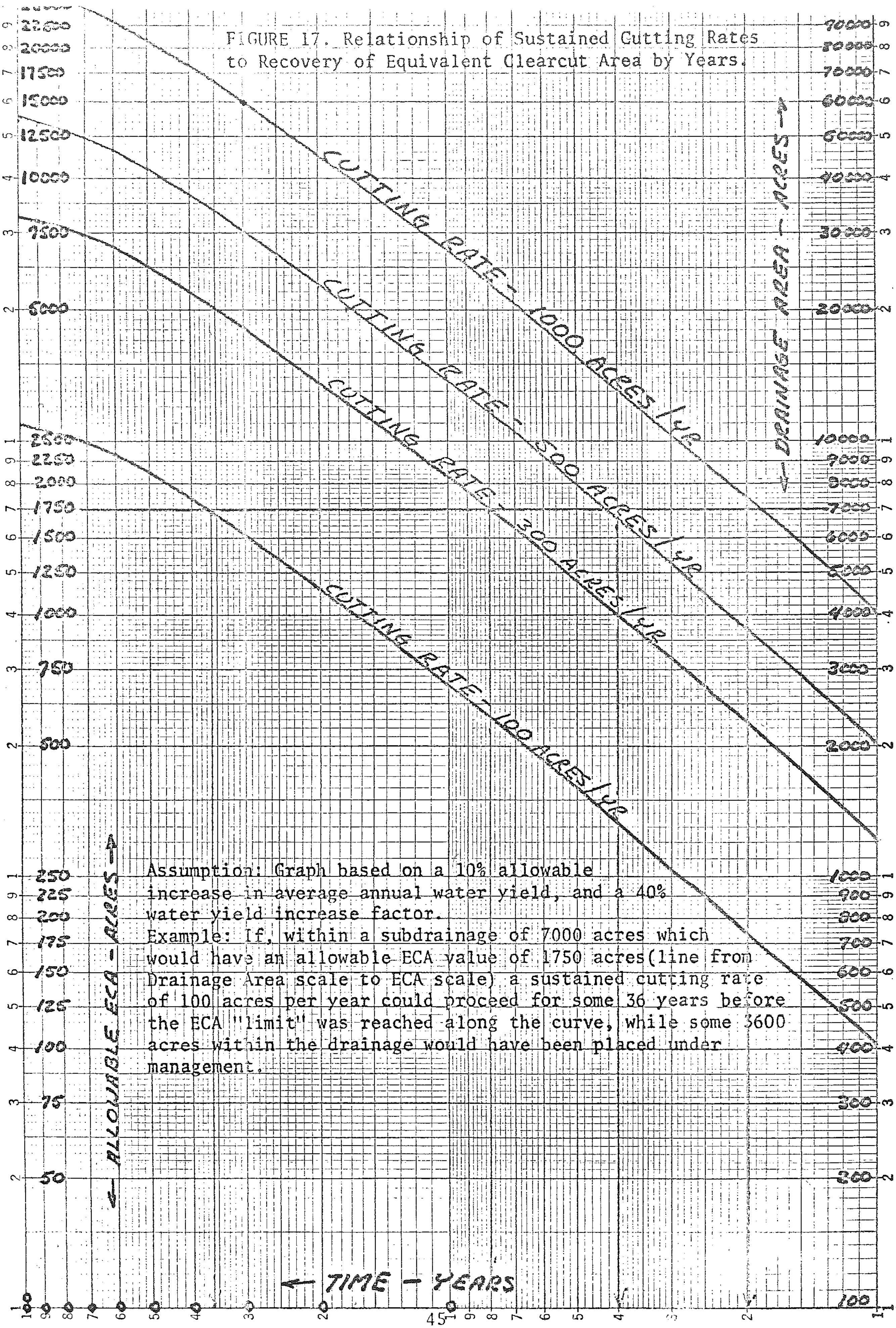


FIGURE 16. Recovery percentage of Equivalent Clearcut Area by Years after Harvest.

Example: If a particular subdrainage contained 500 acres ECA as a result of a timber harvest; after 6 years had elapsed following the the sale, the ECA would have been recovered by 40 % or reduced to some 300 acres.

FIGURE 17. Relationship of Sustained Cutting Rates to Recovery of Equivalent Clearcut Area by Years.



Assumption: Graph based on a 10% allowable increase in average annual water yield, and a 40% water yield increase factor.

Example: If, within a subdrainage of 7000 acres which would have an allowable ECA value of 1750 acres (line from Drainage Area scale to ECA scale) a sustained cutting rate of 100 acres per year could proceed for some 36 years before the ECA "limit" was reached along the curve, while some 3600 acres within the drainage would have been placed under management.

FIGURE 18. Determining the Percentage of a Drainage Area that will be in ECA for selected Increase Limits.

Example: If it was determined that the water yield increase factor for a subdrainage was 35 % and the allowable Increase Limit was set at 7 %, then 20 % of the drainage area could be in an Equivalent Clearcut Area.

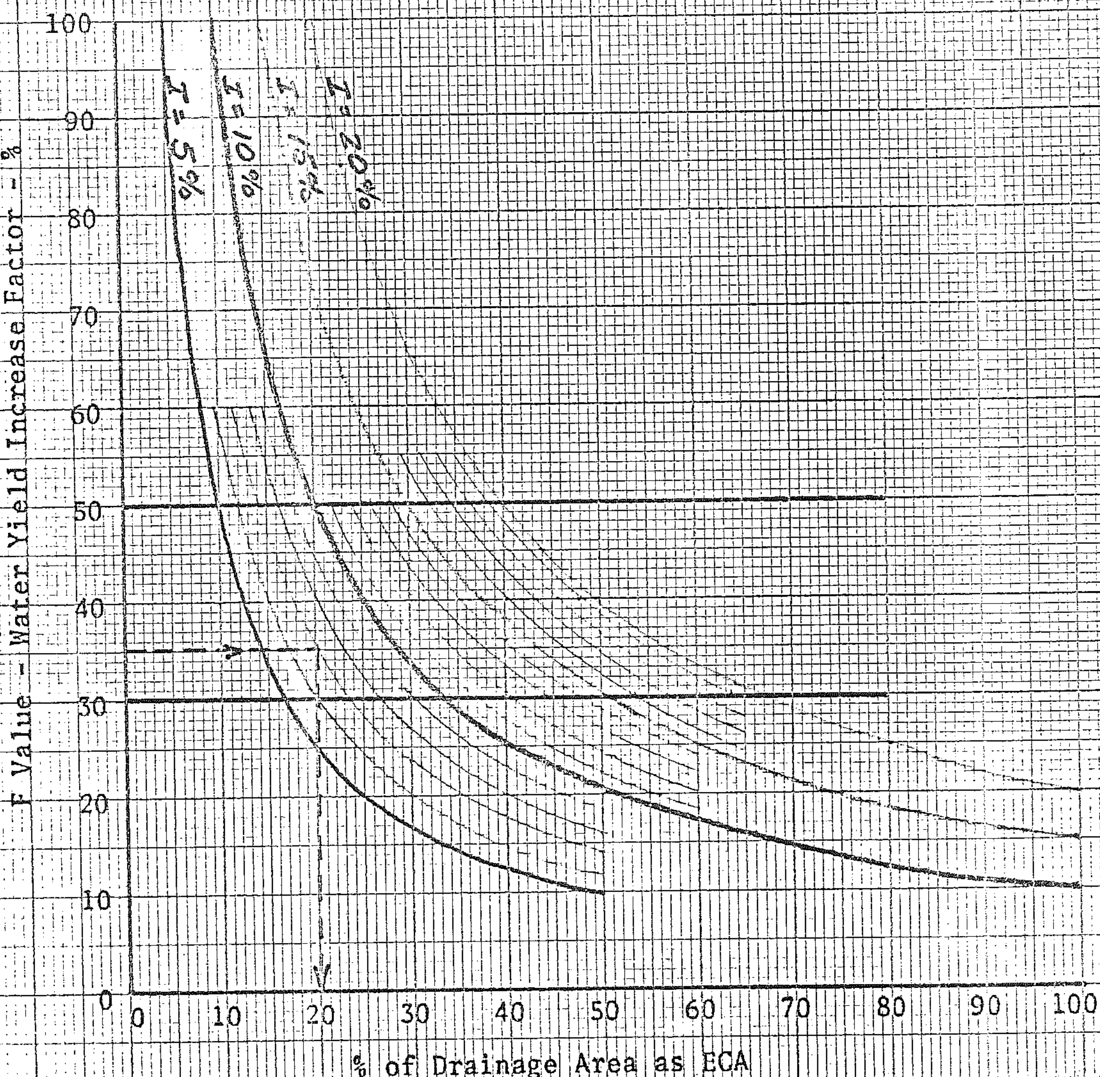


Table ... Changes ... Cutting Rate of 100 Acres/Yr. for 1 thru 100 Years.

Years*	ECA Reduction for a 100-Acre Unit (Acres)	Accumulated ECA (Acres)	Years	ECA Reduction for a 100-Acre Unit	Accumulated ECA	Years	ECA Reduction for a 100-Acre Unit	Accumulated ECA
1	100	100	26	36	1351	52	25	2160
2	85	185	27	36	1387	54	24	2208
3	78	263	28	36	1423	56	23	2254
4	72	335	29	35	1458	58	22	2298
5	67	402	30	35	1493	60	21	2340
6	63	465	31	35	1528	67	20	2380
7	60	525	32	35	1563	64	19	2418
8	58	583	33	34	1597	66	18	2454
9	55	638	34	34	1631	68	17	2488
10	53	691	35	33	1664	70	16	2520
11	51	742	36	33.	1697	72	15	2550
12	50	792	37	33	1730	74	14	2578
13	48	840	38	32	1762	76	13	2604
14	46	886	39	32	1794	78	12	2628
15	44	930	40	31	1825	80	11	2650
16	42	972	41	31	1856	82	10	2670
17	41	1013	42	30	1886	84	9	2688
18	40	1053	43	30	1916	86	7	2702
19	39	1092	44	29	1945	88	6	2714
20	38	1130	45	29	1974	90	5	2724
21	38	1168	46	28	2002	92	4	2732
22	37	1205	47	28	2030	94	3	2738
23	37	1242	48	27	2057	96	2	2742
24	37	1279	49	27	2084	98	1	2744
25	36	1315	50	26	2110	100	0	2745

*For the accumulated trated area at any point, multiply years by 100.

Cutting Rate of 300 Acres/Year for 100 Years.

Years*	ECA Reduction for a 300-Acre Unit (Acres)	Accumulated ECA	Years	Reduction	Accumulated ECA	Years	Reduction	Accumulated ECA
1	300	300	26	108	4053	52	75	6480
2	255	555	27	108	4161	54	72	6624
3	234	789	28	108	4269	56	69	6762
4	216	1005	29	105	4374	58	66	6894
5	201	1206	30	105	4479	60	63	7020
6	189	1395	31	105	4584	62	60	7140
7	180	1575	32	105	4689	64	57	7254
8	174	1749	33	102	4791	66	54	7362
9	165	1914	34	102	4893	68	51	7464
10	159	2073	35	99	4992	70	48	7560
11	153	2226	36	99	5091	72	45	7650
12	150	2376	37	99	5190	74	42	7734
13	144	2520	38	96	5286	76	39	7812
14	138	2658	39	96	5382	78	36	7884
15	13	2790	40	93	5475	80	33	7950
16	126	2916	41	93	5568	82	30	8010
17	123	3039	42	90	5658	84	27	8064
18	120	3159	43	90	5748	86	21	8106
19	117	3276	44	87	5835	88	18	8142
20	114	3390	45	87	5922	90	15	8172
21	114	3504	46	84	6006	92	12	8196
22	111	3615	47	84	6090	94	9	8214
23	111	3726	48	81	6171	96	6	8226
24	111	3837	49	81	6252	98	3	8232
25	108	3945	50	78	6330	100	0	8235

*For accumulated treated area at any point, multiply years by 300.

Cutting a Rate of 500 Acres/Year for 100 Years.

Years*	ECA Reduction for 500-Acre Unit (Acre)	Accumulated ECA	Years	Reduction	Accumulated ECA	Years	Reduction	Accumulated ECA
1	500	500	26	180	6755	52	125	10815
2	425	925	27	180	6935	54	120	11055
3	390	1315	28	180	7115	56	115	11285
4	360	1675	29	180	7295	58	110	11505
5	335	2010	30	175	7470	60	105	11715
6	315	2325	31	175	7645	62	100	11915
7	300	2625	32	175	7820	64	95	12105
8	290	2915	33	175	7995	66	90	12285
9	275	3190	34	170	8165	68	85	12455
10	265	3455	35	170	8335	70	80	12615
11	255	3710	36	165	8500	72	75	12765
12	250	3960	37	165	8665	74	70	12905
13	240	4200	38	160	8825	76	65	13035
14	230	4430	39	160	8985	78	60	13155
15	220	4650	40	155	9140	80	55	13265
16	210	4860	41	155	9295	82	50	13365
17	205	5065	42	150	9445	84	45	13455
18	200	5265	43	150	9595	86	35	13525
19	195	5460	44	145	9740	88	30	13585
20	190	5650	45	145	9885	90	25	13635
21	190	5840	46	140	10025	92	20	13675
22	185	6025	47	140	10165	94	15	13705
23	185	6210	48	135	10300	96	10	13725
24	185	6395	49	135	10435	98	5	13735
25	180	6575	50	130	10565	100	0	13740

*For accumulated treated area at any point, multiply years by 500.

Table 14. Change in Water Yield Increase Volumes ("B") by Various Ave. Annual Runoff Values (R) for Selected Yield Increase Limits in a Sample 1000-Acre Watershed.

DA = 1000 Acres.

Tabular Data in Acre Feet.

R'	A	I5%	I10%	I15%	I20%
.90	900	45	90	135	180
1.00	1000	50	100	150	200
1.10	1100	55	110	165	220
1.20	1200	60	120	180	240
1.30	1300	65	130	195	260
1.40	1400	70	140	210	280
1.50	1500	75	150	225	300
1.60	1600	80	160	240	320
1.70	1700	85	170	255	340
1.80	1800	90	180	270	360
1.90	1900	95	190	285	380
2.00	2000	100	200	300	400
2.10	2100	105	210	315	420
2.20	2200	110	220	330	440
2.30	2300	115	230	345	460
2.40	2400	120	240	360	480
2.50	2500	125	250	375	500
2.60	2600	130	260	390	520
2.70	2700	135	270	405	540
2.80	2800	140	280	420	560
2.90	2900	145	290	435	580
3.00	3000	150	300	450	600

Table 15. Cow Creek Subdrainage Area by Soil Types.

	Data in Acres											
Soil No.	19	19	21	26	27	28	29	32	35	38	38	Total
Slope Class	B	C	C	D	C	D	B	C	B	B	C	
Sub-Drain No.												
I	43	174	236	254				50				757
II	153		161	121	30	129			74		32	700
III					428	10	130		1107	120	460	2255
	196	174	397	375	458	139	130	50	1181	120	492	3712

Data developed from Figure 5A.

Table 16. Composite Soil Erosion Hazard Rating by Soil Types.

Soil Type	19	19	21	26	27	28	29	32	35	38	38	Total
Slope Class	B	C	C	D	C	D	B	C	B	B	C	
Mass Failure	2	2	4	4	4	6	2	6	2	4	6	
Road Cuts	2	2	2	8	8	6	2	4	2	2	4	
Road Beds	2	4	4	8	8	6	2	4	4	2	4	
Skid Trails	2	4	4	8	6	6	2	4	4	2	4	
Nat.Bare Sfc.	4	4	4	8	6	4	0	4	4	2	4	
Dry Creep	2	4	2	8	6	6	4	4	2	2	4	
Totals	14	20	20	44	38	34	12	26	18	14	26	

Relative Soil Hazard Ratings Based on Soil Recon. Report Interpretations (Rpt. Table 4)

Rating	Value for Composite Score	Total Score Range
Very Low	0	0 - 5
Low	2	6 - 14
Moderate	4	15 - 26
High	6	27 - 38
Very High	8	39 - 48

Table 17. Computed Subdrainage Ave. Composite Soil Hazard Rating.

I

	Acres	Comp. Score	Weighted Score
19B	43	14	602
19C	174	20	3480
21C	236	20	4720
26D	254	44	11176
32C	50	26	1300
Total	757		21278 / 757 = 28.1 HIGH

II

	Acres	Comp. Score	Weighted Score
19B	153	14	2142
21C	161	20	3220
26D	121	44	5324
27C	30	38	1140
28D	129	34	4386
35B	74	18	1332
38C	32	26	832
Total	700		18376 / 700 = 26.2 MODERATE

III

	Acres	Comp. Score	Weighted Score
27C	428	38	16264
28D	10	34	340
29B	130	12	1560
35B	1107	18	19926
38B	120	14	1680
38C	460	26	11960
Total	2255	128	51730 / 2255 = 22.9 MODERATE

Table 18. Water Yield Increase Adjustment For Soil Erosion Hazard Rating.

Total Comp. Score Range	Erosion Hazard Rating	Water Yield Increase Adjustment
0-5	VERY LOW	+5%
6-15	LOW	+3%
16-27	MODERATE	0
29-38	HIGH	-3%
39-48	VERY HIGH	-5%

Table 19. Water Yield Increase Adjustment for Stream Channel Condition Rating.

Channel Condition	Cond. Class	Water Yield Increase Adjustment
Excellent	1	+3%
	2	+2%
Good	3	0
	4	0
Fair	5	-1%
	6	-2%
Poor	7	-4%
	8	-8%

Table 20. Cow Creek Water Yield Increase. Adjustment Summary For Stream Channel Condition and Soil Erosion Hazard.

Sub-Drain	Channel Cond. Class	Yield Inc. Adjust. %	Comp. Hazard Rating	Yield Inc. Adjust. %	Net Allow. Yield Inc.
I	6	-2	28.1	-3	5%
II	4	0	26.2	0	10%
III	5	-1	22.9	0	9%

Table 21. Correlation of Stream Habitat Survey Ratings with Stream Channel Survey Ratings.

Channel Condition Survey Transect Score Range			Stream Habitat Survey Percent of Habitat Optinum*
Rating	Score	Class	% Range
Excellent	0-23	1	96-100
	24-30	2	91-95
Good	31-53	3	81-90
	54-60	4	73-80
Fair	61-102	5	67-72
	103-120	6	61-66
Poor	121-150	7	50-66
	151-184	8	0-49

The above comparison may be used to estimate the channel condition rating from existing stream habitat survey data, on an interim basis for initial planning efforts. Where extensive timber sale-road construction development is planned in a drainage it is suggested that a stream channel condition survey be conducted to confirm the estimated rating.

*From R1-2620-9 Summary and Analysis Form, for each drainage.

PART III

Sample Inventory and Analysis for the South Fork of Cow Creek, Salmon River District, Nezperce N.F.

I. Water Resource Inventory and Ave. Annual & Monthly Water Yields

1. See Figure 5 for base map of upper Cow Creek. Map used is 7.5 min. series USGS topographic map; scale 1:24000, or 1 mile = 2.645 inches. At this scale 1 sq. in. = 91.48 acres. Area boundary shown as solid line.

a. Mapable stream courses shown on topog base map.

b. Stream order overlay appears as Fig. 6.

c. Subdrainages delineated per stream order data, with boundaries shown as dashed lines.

d. Stream order data appears as Table 1A. Drainage area data by aspect shown in Table 2A, from Fig. 7.

e. Elevation zones delineated on topog base map at 1000' intervals, with area by elevation data shown in Table 3A.

2. a, b, c. Water yield data for Cow Cr. taken from ARS Publ. 41-141, and shown as overlay in Fig. 8. Water yield by inch-depth zones shown as Table 4A.

3. a, b. Gaging station reference data taken from summary information in Table 5.

TABLE 1A. Stream Channel Orders.

Subdrainage		1st	2nd	3rd	4th	5th	6th	Totals
I	Mi.	5.0	2.1	1.1	.8			
	No.	34	8	3	1			
II	Mi.	5.5	.6	1.3				
	No.	21	4	1				
III	Mi.	11.5	7.0	1.5	2.3			
	No.	61	17	6	1			
	Mi.							
	No.							
	Mi.							
	No.							
	Mi.							
	No.							
Totals	Mi.							
	No.							
Ave. Chan. Lengths	Ave.	.20	.27	1.1	1.6			

TABLE 2A Drainage Area by General Aspect; North, South, East, and West.

Subdrain.		N	S	E	W	Total
I	A	392	272	82	9	757
	%	51.9	35.9	10.9	1.3	
II	A	310	180	210	---	700
	%	44.3	25.7	30.0	---	
III	A	1107	41	902	205	2255
	%	49.1	1.8	40.0	9.1	
	A					
	%					
	A					
	%					
	A					
	%					
Total	A					
	%					

A = Area, Acres   % = Percent of subdrainage area

TABLE 3.A. Drainage Area by Elevation Zones.

Subdrain.		2-3000	3-4000	4-5000	5-6000	6-7000	7000 +	Total
I	A	-	68	483	205	-	-	757
	%		8.9	63.8	27.3			
II	A	-	46	244	410			
	%		6.6	34.9	58.5	-	-	700
III	A	-	77	674	1194	310	-	2255
	%		3.4	29.9	52.9	13.8		
	A							
	%							
	A							
	%							
	A							
	%							
Total	A							
	%							

A = Area, Acres
% = Percent of subdrainage area
AF = Acre Feet of Water
AF÷ A = Ave. Runoff in Feet for Drainage.

TABLE 4A. Runoff or Water Yield by Inch-Depth Zones.

Subdrain.	In / Ft.	5 / .42	8 / .67	10 / .83	12 / 1.00	15 / 1.25	20 / 1.67	22 / 1.83			Total
I	A	46	137	246	242	86					757
	AF	19	92	204	242	108				(.87)	665
II	A	18	118	109	182	273					700
	AF	8	79	90	182	341				(1.00)	700
III	A	27	223	310	406	706	433	150			2255
	AF	11	149	257	406	883	723	275		(1.20)	2704
	A										
	AF										
	A										
	AF										
	A										
	AF										
Total	A	91	478	665	830	1065	433	150			3712
	AF	38	320	551	830	1332	723	275			4069

TABLE 6A. Monthly Water Yields for Drainage Area & Subdrainages.

Water Year	O	N	D	J	F	M	A	M	J	J	A	S	Annual
Monthly % of Annual Yld.	2.9	3.0	3.3	2.9	3.6	5.1	13.2	29.4	25.3	6.6	2.6	2.1	
Drainage Area Yield I, II & III	118	112	134	118	146	208	537	1196	1029	269	106	86	4069
Subdrain. I	19	20	22	19	24	34	88	196	168	44	17	14	665
II	20	21	23	20	25	36	93	206	177	46	18	15	700
III	78	81	89	78	97	140	357	795	684	178	70	57	2704

Percentage data developed from streamflow records at Salmon R. @ White Bird & N. Fk. Skookumchuck Cr.

c. Table 6A displays water yield for Cow Cr. and subdrainages on monthly basis.

d. The estimated monthly water yield for Subdrainage III (in acre feet) is plotted as a hydrograph in Fig. 4.

Ave. Runoff = Ann. Water Yield in A.F. ÷ Drainage Area in Acres.

II. Effects of Timber Cutting on Water Yields

1, 2. The allowable Equivalent Clearcut Area for Subdrainage III as shown previously is 564 acres.

Note: Unless otherwise indicated, use an "F" value (or water yield increase factor) in the described formulas of 40% for those areas on the Nezperce between 4000 and 6000 ft. elevations.

3. Calculate existing or planned ECA. Determine Increase in Average Annual Yield.

a. In the example of the S. Fk. Cow Cr., planned development is shown in Figure 9. The following Table 8 is a summary of assumed development data for the subdrainage. The ECA values for partial cut units are obtained through Fig. 10.

Table 8. Subdrainage III ECA Summary

Cutting Unit No.	Type of Unit	% Cut	Treated Area (Ac)	ECA
1	CC	100	91	91
2	CC	100	78	78
3	PC	60	41	27
4	PC	48	55	20
5	CC	100	55	55
6	CC	100	69	69
7	PC	50	123	52
8	CC	100	50	50
9	CC	100	55	55
Roads	(CC)	100	25	25
			642 acres	522 acres

Using Formula II to determine the "I" value for the above calculated ECA, where:

I = ECA x R = Y x F = B ÷ A

I = 522 x 1.20' = 626 x .40 = 250 ÷ 2704

I = 9.2%

4. Plotting the Water Yield Increas Volume over the Hydrograph for Subdrainage III.

a. The percentage values to apply to the "B" value (in Formula II) from Table 7 are, in this case, an average of the north and east aspects for the 4500-6000 ft. elev. zone.

	Mar	Apr	May	June	July	Aug	
b. Ave. % values of N&E aspects	0	7.5	37.5	40.0	10	5	%
Monthly distribution of "B"; ie: 250 AF	0	19	94	100	25	12	A.F.

c. The monthly water yield increase volumes are plotted over the average annual hydrograph (Fig. 4) and connected with a dashed line to show the "after treatment" hydrograph.

5. Maximum Channel Impact Period. Increase in Peak Flows.

a. The maximum channel impact period for the S. Fork of Cow Creek is estimated at 56 days, from Fig. 4. The increase in the maximum channel impact period is estimated at 13 days, or a 23% increase due to timber cutting and water yield increases.

b. The peak flow increase is estimated at 93 acre feet, or a 11.6% increase; i.e.: From Table 6A the ave. flow for May is 795 AF; from the monthly distribution of the water yield increase volume, the added flow for May is 93 AF.

PART IV

Timber Cutting Guidelines for Use on the Nezperce National Forest

The primary guideline prescribed for use on the Nezperce National Forest concerning the relation of water yield increase to timber harvesting is the amount by which the average annual water yield of a 3rd to 5th order drainage will be increased as a result of removal of the timber cover.

Information from other areas in the Region and analyses of local water yield occurrence frequencies indicate that when the average annual water yield of a drainage is increased by more than 10%, channel degradation and aggradation will begin to accelerate. This applies generally to those drainages which have a "good" stream channel condition rating and a "moderate" potential for soil erosion. While the average allowable increase limit of 10% is presented as a primary guideline, it may also be adjusted up or down, dependent on individual drainage channel conditions and soil erosion potentials.

Primary Guideline:

1. Proposed timber harvest activities should not develop more than a 10% increase in the average annual yield of a 3rd to 5th order drainage.

Secondary Guidelines:

2. The peak flow volume or the highest average monthly yield should not be increased more than 15 to 20%.

3. The "maximum channel impact" period should not be increased more than 20%.

General guides relating to flow timing, stream channel conditions, natural regeneration, and on-site impacts, i.e.: water quality.

4. Avoid the following:

a. Concentration of cutting in the same elevation zone on north slopes.

b. Cutting next to or along both sides of the main drainageway.

c. Reducing the intervening strip between clearcuts to a width less than 8-10 tree heights.

d. Cutting within the intervening strip of timber until the adjacent cutting unit has an ECA recovery of at least 60%.

e. Developing more than 20 to 25% ECA in a 3rd to 5th order drainage.

f. Clearcutting closer than 3½ chains or 250 feet slope distance to a 3rd order or higher drainage channels below 5000 feet elevation. Above 5000 feet, buffer strip may be reduced to two chains. Timber within such leave strips may be partially cut on a salvage basis, but not to exceed 35% crown removal (in a fully stocked stand).

g. Laying out clearcut blocks greater than 35 acres with:

(1) south or west exposures

(2) slope gradients over 35%

(3) elevations below 5000 feet

5. Should a "silvicultural emergency" develop, the intervening strip between clearcuts may be partially cut, but not to exceed 30% crown removal from a fully stocked stand.

PART V

Information Needed to Conduct a "Water Balance" Analysis with Use of an Existing Computer Program.

1. Mean monthly air temperatore (^{o}F) from nearest U.S. Weather Bureau or Forest Service station of record. Data can be extrapolated to the drainage area in question.

2. Mean monthly precipitation (inches). Again, use nearest available data of record. Data can be extrapoloated to the drainage area.

3. Latitude and longitude of drainage area (degrees and minutes).

4. General aspect expressed in degrees from true north; and average slope percent of drainage area or sub-unit.

5. Mean elevation of the drainage area, or area by elevation zones in 800- or 1000-foot increments.

6. Total drainage or sub-unit area in acres. Total area in acres to be treated by type of treatment; i.e., area to be clearcut, partial cut with cutting density; and area of existing cutting with age of treatment.

7. Vegetation: What is general type and age of timber within drainage area. Approximate percent of area occurring as grass or brush.

8. Roads: Miles, width, type, of existing and planned roads.

9. Soils: Average depth; estimate of texture, i.e., sandy loam, silt loam, etc. General type such as Granitic, Belt, Loess, Glacial, etc.

10. Accompany data above with map of drainage to be evaluated. Delineate drainage-subdrainage boundary, and existing and/or probable treatment units. (Suggest 2"/mile scale topog. map.)

PART VI

Discussion Concerning the Relationship of Timber Cutting to Water Yield

- An excerpt from "Vegetation Manipulation Guides - Flathead National Forest" by Robert Delk, Hydrologist.

DISCUSSION

In order to use the guidelines, one must accept the basic premise that water yield is increased following vegetation removal. Hibbert (1967) summarized thirty-nine studies which dealt with the effect of manipulating forest cover on water yeild. Essentially, the studies proved that reducing forest cover increased water yield and that increasing forest cover decreased water yield. Hibbert concluded from the study that in areas of abundant precipitation, such as the Flathead, increases in streamflow are proportional to reduction of forest cover. First-year response to clear-cutting varied from 22 to 80% increase in mean annual streamflow. Increases in streamflow decline as the forest regrows. Seasonal distribution of streamflow response is dependent upon climate and landform as well as other factors.

Hoover (1969) reported on the Fool Creek study in Colorado:

"A 714-acre watershed called Fool Creek was cut in 1955 after a 13-year calibration period with an adjacent stream. Thirty-nine percent of the watershed was cut in strips alternating with uncut forest. The cleared strips range in width from 1 to 6 chains (1 chain = 66 feet).

Comparisons of snowpack in the alternate forest and clearcut strips indicate that there is more water equivalent in the open strips. Despite this difference, there seems to be no increase in the total snow storage on the watershed. There is a pronounced redistribution of snow as a result of the cutting, and now more snow is found in the cut strips and less in the uncut forest.

The reason for redistribution of the snowpack is the effectiveness of the openings in trapping snow transported from intervening forested strips. Before cutting, wind action distributed the snow rather evenly within the forest. Now, the openings increase the wind stress on the remaining forest canopy and efficiently trap snow that formerly settled in adjacent forested strips.

Water Yield--Removing timber from Fool Creek watershed has increased the water yield by more than 25 percent. Most of the increase is due to a substantially enlarged spring runoff. There is very little increase in streamflow during the late summer and early fall months. Thirteen years have lapsed without any indication that the effect of harvest cutting on streamflow has diminished. Also, the increase in runoff is higher during wet years than dry years.

The cutting of trees and resultant redistribution of the seasonal snowpack has substantially increased runoff from Fool Creek watershed. Three probable reasons for this are: (1) some water, which was formerly used to replace soil moisture consumed by vegetation, is now available for streamflow; (2) more snow is deposited in the openings where soil moisture deficits are least; and (3) the snow in the openings is exposed to evaporation for a shorter time. Melt rates are more rapid in the openings than in the forest. This acceleration of input holds down losses still further."

Fool Creek is a high elevation area in the Colorado Rockies where, like the Flathead, the majority of annual precipitation is in the form of snow. Seasonal streamflow at Fool Creek is also similar to the Flathead in that there is a high-peak runoff during the spring snowmelt period.

Anderson (1966) concluded from several studies concerned with snowpack management that:

1. "Maximum increase in yield will result from cutting of trees or removal of brush from areas of deep soils, from areas with direct drainage to channels (slopes adjacent to channels or strips perpendicular to contours), from areas of least runoff per unit precipitation (densest forests, sites with most heat, and/or frequent drying)."

2. "Maximum delay in yield will result from piling of snow, as in cut strips or by snow fences, by maximizing the length of water flow paths (as by clearcut strips from ridge to channel), and by removing riparian vegetation along the adjacent to streams."

3. "Maximum flood prevention will result from (a) maintaining maximum use of water by vegetation (in order: no cutting, selective cutting, strip cutting on contour, other types of cutting, and maintaining deep-rooted vegetation on deep soils and adjacent to channels); (b)

maximizing lengths of water flow paths (maintenance of surface infiltration and deep percolation, prevention of soil freezing, and draining roads away from channels); (c) maximizing diversity of snowmelt (selective cutting on south slopes with no cutting or strip cutting on north slopes, also drifting of snow with natural or artificial barriers)."

4. "Sediment damages may be minimized by (a) preventing erosion (patch or contour strip cutting on steep slopes, leaving strips of trees adjacent to channels of headwater streams, keeping road fills away from streams, revegetating road cuts and fills, spilling road-drainage water away from channels); (b) maintaining channel bottoms and bank stability with vegetation, with rip-rap, or with check dams at critically unstable spots; (c) using care in logging (location of landings out of drainages, diversion of skid trails after use, removal of temporary stream crossings, after logging covering soil with pulverized slash on critical sites); and (d) using care in type conversions (contour piling of brush in brush removal, seeding of grass on critical sites)."

Schmidt's undated report listed a number of conclusions that are also pertinent to the Flathead. An increase in water yield will occur primarily during the spring-melt period in an area of limited summer precipitation where most of the total runoff is from snowpack melt. More increase in water yield occurs from treatments on low-energy slopes than from comparable treatments on high-energy slopes.

Another study (Wilm and Dunford, 1948) was conducted in mature lodgepole pine in which twenty 5-acre plots were arranged in four randomized blocks and sixteen of them were cutover by selective-cutting methods. Snow disappeared from all plots at approximately the same time, however, melting was more rapid on the cut-over plots. The larger amounts of snow in the cut-over areas melted in about the same time as the lesser amounts in the uncut areas. Water available for streamflow on uncut plots amounted to 10.34 inches, or about 42 percent of total annual precipitation (24.5 inches). In contrast, the heavily cut-over plots yielded 13.52 inches, an increase of 31 percent in the quantity available for streamflow.

In the Big Horn Mountains in Wyoming, clear-cutting mature lodgepole pine in blocks of 5, 10, and 20 acres increased peak snow accumulation over that of uncut stands (Berndt, 1965). The peak snowpack water equivalent of the blocks averaged about 2.5 inches or 40 percent greater than that of the uncut forest. However, snow persisted in the uncut stands approximately ten days longer than in the cut-over areas.

Hillman (1971) concludes that creation of openings larger than twenty acres, or with any dimension greater than four times the height of the remaining timber, results in a measurable increase in one or more of the following: snow accumulation, snowmelt rates, and water yield.

The Interception Process

The amount and character of snow interception by forests is greatly influenced by weather factors. The composition of the snow, excluding all other variables, is also important in the interception process. Density, moisture content, type of flakes and the cohesive and adhesive characteristics of the snow affect the amount that will be intercepted and its persistence in the tree crown.

Generally, as the temperature rises to the freezing point of water, the adhesion of snow to foliage increases. This may be partly due to the tendency of falling snow to have a greater moisture content if it occurs during near freezing temperatures. Miller (1964) referred to several studies where wet snow was observed to cling to trees more than dry snow. Baldwin (1957) further commented that more high-density snow is intercepted by tree crowns than low-density snow. To have an accumulation of intercepted snow, adhesion must first occur forming a base on which new snow will fall and, through cohesive action, be retained. The high-density snow has a greater tendency to adhere to foliage than does the low-density snow. Thus, if the snowfall is wet, the interception process will begin sooner and result in a larger accumulation in the crown.

Once the interception process has begun, the cohesive action of the snow which adds to the mass is accomplished by two major processes. The first is the interlocking action of fresh, dendritic flakes. The second process is the sintering action which takes place in response to temperature and wind effects (Miller, 1964). The adhesive and cohesive forces of the snow must be great enough to counter the force of gravity on the angle of repose. High-density snow, even with its greater weight, is more resistant to gravity than low-density snow, primarily due to the greater adhesive and cohesive characteristics of high-density snow. A wet snow which has been on a tree for twenty-four hours can be resistant to wind and gravity and often will not be fully dislodged even by violent shaking.

A study (Japan, 1952) cited by Miller (1964) indicates that snow loads on foliage are less at lower temperatures than at temperatures near freezing. Kuriowa (1962) and Minsk (1961) have shown that adhesion is temperature dependent and increases as temperature rises toward freezing. Hoover and Leaf (1966), on the other hand, report that low air temperatures correlated with maximum interception retention. Temperatures from -10° to +21°F. resulted in greater interception retention than did higher temperatures. In this study, however, snowfall occurred in the relatively warm month of April when the amount of interception was less and it was retained for a shorter period of time Hoover and Leaf (1966) suggested that rimming might be responsible for adhesion rather than high temperatures. Rimming is an important factor on certain areas on the Flathead. No mention is made, however, of other factors such as relative humidity, amount of sunlight of storm intensity and duration of retention. If the lower temperatures are accompanied by a storm of low intensity and long duration, interception retention may be greater than if the temperatures are higher but accompanied by a short duration storm of high intensity.

Once snow has started to accumulate on the foliage, the duration of retention depends largely on the amount of solar radiation incident upon the canopy. If a cloud cover is present, there may not be sufficient diffuse radiation to cause evaporation or mass transport of the snow from the canopy. As the cloud cover is dissipated, the effect of the solar radiation is dependent, in part, upon the characteristics of the intercepted snow. Solar radiation in the winter on the Flathead is quite low and may not provide enough energy to cause evaporation.

Sellers (1965) reports a fresh snow albedo on a bare or open area to be .75 to .95 while the old snow albedo ranges from .40 to .70. Reifsnyder and Lull (1965) state that snow has the highest albedo in nature. Miller (1955) determined that the albedo of one-day old snow varied little with the season and region and had an average value of .84 with a standard deviation of .03. Miller (1962) also stated that intercepted snow in a canopy can reduce effective radiation by fifty percent when compared to a snow-free canopy. Leonard and Eschner (1968) took albedo readings from a tramway above a conifer canopy. Their findings indicated that the albedo was usually less than .20, which tends to refute the generally accepted suggestion that intercepted snow has a high reflectivity.

Anderson's (1956) study was concerned with snowpack accumulation in relation to various cutting practices, the results of which might be applied to interception problems. The study indicated that maximum accumulation occurred where there was sixty-five percent shading and forest openings extended to the north. In comparing the effects of shading from trees on the south with radiation effects from trees on the north, it was found that shade was about twice as effective in preserving the snowpack as the radiation was in reducing the pack. It may follow that if intercepted snow were subjected to significant amounts of shade, it could remain on branches longer than exposed snow.

These studies all seem to indicate that the amount of solar radiation incident upon the canopy and the albedo of the canopy are important factors in determining the final disposition of the intercepted snow. It is generally agreed that the albedo of snow on the ground is quite high and Miller (1962) feels that the albedo of intercepted snow in the canopy is also high. If Miller's (1962) suggestion is correct, there may not be sufficient energy to facilitate evaporation or removal of snow from the canopy. Results for Leonard and Eschner's (1968) study indicate, however, that more research on the albedo of intercepted snow is needed before conclusions can be drawn.

This study does point out the problems encountered in obtaining data on intercepted snow. The low albedo obtained could be due to a number of factors which were not considered in the study. For example, depth of snow on the canopy was judged to be approximately 100mm, which is a relatively thin layer compared to the average snowpack found in the western United States. There was also some mass movement of snow which exposed bare foliage and further reduced the albedo.

Wind Effects on Interception

It has often been observed that snow accumulation is greater in the openings than in the adjacent forest stands. Some observers attributed this difference to sublimation of intercepted snow and concluded that the difference between snow depth in the opening and snow depth in the forest represented the amount of interception loss caused by forest canopies. This difference, however, may be related to a differential deposition of snow in the openings during the precipitation events or a result of wind and aerodynamic relationships between the forest and adjacent openings. Jaenicke and Foerster (1915) found no consistent relationship between the amount of snowfall in an opening and snowfall in a forest. They observed that snow was evenly distributed in the opening and unevenly distributed in the forest.

Miller (1964) cites several studies in which interception was greater at the forest boundaries and on the slopes than in the forest center and on level ground. It was suggested that the difference was due to differential deposition, however, the amount of snow intercepted by the canopy due to wind effects alone cannot really be determined. Falling snow on a forest is often deposited in larger amounts on the windward side of an opening which results in some dificit on the leeward side of the forest (Anderson and Gleason, 1959). Snow density and surface characteristics of the intercepting media are involved in the interception process. According to Russian and Finnish papers cited by Miller (1964), under relatively high wind condtions, the interception of wet snow is greater than dry snow. This would be a logical conclusion since wet snow tends to be more adhesive than dry snow. Hoover and Leaf (1966), however, found little evidence of snow adhesion on conifer foliage. Rather, accumulation began when snowflakes came to rest at the base of needles. Under windy conditions most snowflakes bounced off the needles and did not slide down to the base.

In the Russian and Finnish studies (Miller, 1962) accumulation took place in high steady winds where the snow was literally "plastered" to the trees. In the Hoover and Leaf (1966) study, there was considerable cold air drainage at night and gusty, turbulent winds during the day, which prevented snowflakes from coming to rest on the needles. Miller (1964) pointed out that the angle of delivery of snow to the forest canopy may affect retention as much as the rate of delivery. Wind approaching at a low angle will contact more canopy surface area than a wind with a high-approach angle and may result in greater interception. Thus, a low wind velocity may increase interception rates while a high wind velocity will probably cause less snow to be retained by the canopy. Maximum snow accumulation in the crowns will probably occur at low wind speeds with temperatures near 32°F. (Miller, 1964).

It is essential that the first snowflakes are trapped by the needles for accumulation to occur. From there cohesive bonds develop which allow accumulation to progress beyond the needle tip. If wind velocities were sufficiently turbulent to prevent initial trapping of the snowflakes by the foliage, then the total accumulation was reduced. If wind velocities were high and blowing at a steady rate, the "plastering" phenomenon might result.

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Wisler and Brater (1965) describe evaporation as a vapor pressure gradient phenomenon by Dalton's Law, $E = C(pw - pa)$ where E = evaporation in inches of water per day; C = a coefficient related to barometric pressure, wind velocity and other climatological variables; pw = maximum vapor pressure corresponding to the temperature of the water surface; pa = vapor pressure in the air above the water surface. This vapor pressure gradient is, in turn, affected by wind velocity, temperature, relative humidity and, when discussing snow, the moisture content of the snow. Water vapor removed from the snow surface is then dispersed by diffusion, convection, and wind action.

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The net effect of incoming solar radiation is dependent upon the absortivity and reflectivity of the receiving suface. As mentioned above, the albedo of snow is generally considered to be quite high. Leonard and Eschner (1968), however, have suggested albedo values less than .20 for a snow-covered forest canopy. Gerdel (1948) found that the depth of which radiation penetrated a snowpack increased as snow density decreased. If ice and slush were present in the snow, the albedo was decreased with a corresponding increase in radiation absorption. This resulted in a reduction in the amount of radiation transmitted through the ice and slush layer to the lower horizons in the snow.

Goodell (1966) suggested that the mere existence of snow indicates conditions of low evaporation rates. With short-wave albedos of .60 and .80, available energy and vapor pressure gradients necessary to cause evaporation are severely limited. Martinelli (1960) found that summer evaporation losses from alpine areas were probably balanced by condensation. Seasonal evaporation rates in the Sierra Nevades were found to vary with the topographic exposure and density of forest cover (West, 1962). Goodell (1963) suggested that evaporation from intercepted snow was greatly limited by a lack of energy required to vaporize snow. Although sufficient energy may be available fro evaporation, the distribution of radiation, the surface roughness, and the characteristics of the snow may combine to prevent significant evaporation from occurring.

Snow, which has a high albedo for short-wave radiation, is almost a perfect absorber for long-wave radiation (Reifsnyder and Lull, 1965). Conversely, the forest is a slightly better reflector of long-wave radiation and deters long-wave radiation at night upon the snowpack (Anderson, 1963). The net effect of long-wave radiation on snow in the canopy will be determined by the temperature on the snow surface and the leaves as well as the amount of forest cover. Miller (1966) states that the long-wave energy flux from clouds to the intercepted snow is probably larger than the short-wave radiation at almost every location. Long-wave radiation is greatest during the snow storm and decreases rapidly after the clouds dissipate and the air becomes colder and drier. The quantitative effect of this long-wave radiation on newly deposited snow is not known.

A study to determine the effects of long-wave radiation on snow melt in a forest would be of great value. While quantitative data are not available, we can make some assumptions concerning long-wave radiation. Due to energy available from long-wave radiation, bare foliage surfaces begin to appear in the canopy. These bare areas, with a relatively low albedo, absorb more short-wave radiation, thus increasing melt rates of the intercepted snow. Energy from long-wave radiation becomes more important as the amount of bare foliage surface becomes larger. In a relatively discontinuous canopy, long-wave radiation is utilized by adjacent trees, while in a smoother canopy, long-wave energy may be lost to the atmosphere.

Another major energy source for removing intercepted snow is sensible heat. If conditions exist where air is warmer than the snow layers, there is some energy transfer from air to snow due to turbulence. Satterlund and Eschner (1965) pointed out that even if no temperature gradient exists, there will still be vapor movement from snow to air if a vapor pressure gradient is present. As the vapor leaves the snow layer, the snow surface cools, thereby creating a temperature gradient. The whole system then cools until both the temperature gradient and the vapor pressure gradient are in equilibrium.

From Sverdrup's equations for turbulent heat and vapor transfer to or from a snow surface, Satterlund and Eschner (1965) have calculated that differences in roughness parameters between the forest canopy and the open field are probably the best factors to consider in the determination of evaporation differences between the two areas. They concluded that, if the other elements of the equation remain constant, the effects of surface roughness can be significant. This difference in evaporation rates is due, in part, to the greater transfer of sensible heat in a forest canopy situation.

Evaporation, while easy to explain on a theoretical or mechanical basis, is difficult to determine quantitatively. A vapor pressure gradient must be present for evaporation to take place. The presence of this gradient is due, partly, to wind veolcity, temperature of air and snow and the moisture content of the air and snow. There must also be sufficient energy available to promote the evaporation process. This energy is dependent upon short-wave radiation, long-wave radiation and advected sensible heat. The efficiency of this energy distribution is, in turn, dependent upon surface roughness and albedo. The entire interception-evaporation process is complex and the determination of evaporation rates from the snow intercepted by a forest canopy is difficult. Research techniques are needed that will permit quantitative measurements to be taken from the intercepted snow while it is still on the canopy.

DISCUSSION

In order to use the guidelines, one must accept the basic premise that water yield is increased following vegetation removal. Hibbert (1967) summarized thirty-nine studies which dealt with the effect of manipulating forest cover on water yield. Essentially, the studies proved that reducing forest cover increased water yield and that increasing forest cover decreased water yield. Hibbert concluded from the study that in areas of abundant precipitation, such as the Flathead, increases in streamflow are proportional to reduction of forest cover. First-year response to clear-cutting varied from 22 to 80% increase in mean annual streamflow. Increases in streamflow decline as the forest regrows. Seasonal distribution of streamflow response is dependent upon climate and landform as well as other factors.

Hoover (1969) reported on the Fool Creek study in Colorado:

"A 714-acre watershed called Fool Creek was cut in 1955 after a 13-year calibration period with an adjacent stream. Thirty-nine percent of the watershed was cut in strips alternating with uncut forest. The cleared strips range in width from 1 to 6 chains (1 chain = 66 feet).

Comparisons of snowpack in the alternate forest and clearcut strips indicate that there is more water equivalent in the open strips. Despite this difference, there seems to be no increase in the total snow storage on the watershed. There is a pronounced redistribution of snow as a result of the cutting, and now more snow is found in the cut strips and less in the uncut forest.

The reason for redistribution of the snowpack is the effectiveness of the openings in trapping snow transported from intervening forested strips. Before cutting, wind action distributed the snow rather evenly within the forest. Now, the openings increase the wind stress on the remaining forest canopy and efficiently trap snow that formerly settled in adjacent forested strips.

Water Yield--Removing timber from Fool Creek watershed has increased the water yield by more than 25 percent. Most of the increase is due to a substantially enlarged spring runoff. There is very little increase in streamflow during the late summer and early fall months. Thirteen years have lapsed without any indication that the effect of harvest cutting on streamflow has diminished. Also, the increase in runoff is higher during wet years than dry years.

The cutting of trees and resultant redistribution of the seasonal snowpack has substantially increased runoff from Fool Creek watershed. Three probable reasons for this are: (1) some water, which was formerly used to replace soil moisture consumed by vegetation, is now available for streamflow; (2) more snow is deposited in the openings where soil moisture deficits are least; and (3) the snow in the openings is exposed to evaporation for a shorter time. Melt rates are more rapid in the openings than in the forest. This acceleration of input holds down losses still further."

Fool Creek is a high elevation area in the Colorado Rockies where, like the Flathead, the majority of annual precipitation is in the form of snow. Seasonal streamflow at Fool Creek is also similar to the Flathead in that there is a high-peak runoff during the spring snowmelt period.

Anderson (1966) concluded from several studies concerned with snowpack management that:

1. "Maximum increase in yield will result from cutting of trees or removal of brush from areas of deep soils, from areas with direct drainage to channels (slopes adjacent to channels or strips perpendicular to contours), from areas of least runoff per unit precipitation (densest forests, sites with most heat, and/or frequent drying)."

2. "Maximum delay in yield will result from piling of snow, as in cut strips or by snow fences, by maximizing the length of water flow paths (as by clearcut strips from ridge to channel), and by removing riparian vegetation along and adjacent to streams."

3. "Maximum flood prevention will result from (a) maintaining maximum use of water by vegetation (in order: no cutting, selective cutting, strip cutting on contour, other types of cutting, and maintaining deep-rooted vegetation on deep soils and adjacent to channels); (b)

maximizing lengths of water flow paths (maintenance of surface infiltration and deep percolation, prevention of soil freezing, and draining roads away from channels); (c) maximizing diversity of snowmelt (selective cutting on south slopes with no cutting or strip cutting on north slopes, also drifting of snow with natural or artificial barriers)."

4. "Sediment damages may be minimized by (a) preventing erosion (patch or contour strip cutting on steep slopes, leaving strips of trees adjacent to channels of headwater streams, keeping road fills away from streams, revegetating road cuts and fills, spilling road-drainage water away from channels); (b) maintaining channel bottoms and bank stability with vegetation, with rip-rap, or with check dams at critically unstable spots; (c) using care in logging (location of landings out of drainages, diversion of skid trails after use, removal of temporary stream crossings, after logging covering soil with pulverized slash on critical sites); and (d) using care in type conversions (contour piling of brush in brush removal, seeding of grass on critical sites)."

Schmidt's undated report listed a number of conclusions that are also pertinent to the Flathead. An increase in water yield will occur primarily during the spring-melt period in an area of limited summer precipitation where most of the total runoff is from snowpack melt. More increase in water yield occurs from treatments on low-energy slopes than from comparable treatments on high-energy slopes.

Another study (Wilm and Dunford, 1948) was conducted in mature lodgepole pine in which twenty 5-acre plots were arranged in four randomized blocks and sixteen of them were cutover by selective-cutting methods. Snow disappeared from all plots at approximately the same time, however, melting was more rapid on the cut-over plots. The larger amounts of snow in the cut-over areas melted in about the same time as the lesser amounts in the uncut areas. Water available for streamflow on uncut plots amounted to 10.34 inches, or about 42 percent of total annual precipitation (24.5 inches). In contrast, the heavily cut-over plots yielded 13.52 inches, an increase of 31 percent in the quantity available for streamflow.

In the Big Horn Mountains in Wyoming, clear-cutting mature lodgepole pine in blocks of 5, 10, and 20 acres increased peak snow accumulation over that of uncut stands (Berndt, 1965). The peak snowpack water equivalent of the blocks averaged about 2.5 inches or 40 percent greater than that of the uncut forest. However, snow persisted in the uncut stands approximately ten days longer than in the cut-over areas.

Hillman (1971) concludes that creation of openings larger than twenty acres, or with any dimension greater than four times the height of the remaining timber, results in a measurable increase in one or more of the following: snow accumulation, snowmelt rates, and water yield.

The Interception Process

The amount and character of snow interception by forests is greatly influenced by weather factors. The composition of the snow, excluding all other variables, is also important in the interception process. Density, moisture content, type of flakes and the cohesive and adhesive characteristics of the snow affect the amount that will be intercepted and its persistence in the tree crown.

Generally, as the temperature rises to the freezing point of water, the adhesion of snow to foliage increases. This may be partly due to the tendency of falling snow to have a greater moisture content if it occurs during near freezing temperatures. Miller (1964) referred to several studies where wet snow was observed to cling to trees more than dry snow. Baldwin (1957) further commented that more high-density snow is intercepted by tree crowns than low-density snow. To have an accumulation of intercepted snow, adhesion must first occur forming a base on which new snow will fall and, through cohesive action, be retained. The high-density snow has a greater tendency to adhere to foliage than does the low-density snow. Thus, if the snowfall is wet, the interception process will begin sooner and result in a larger accumulation in the crown.

Once the interception process has begun, the cohesive action of the snow which adds to the mass is accomplished by two major processes. The first is the interlocking action of fresh, dendritic flakes. The second process is the sintering action which takes place in response to temperature and wind effects (Miller, 1964). The adhesive and cohesive forces of the snow must be great enough to counter the force of gravity on the angle of repose. High-density snow, even with its greater weight, is more resistant to gravity than low-density snow, primarily due to the greater adhesive and cohesive characteristics of high-density snow. A wet snow which has been on a tree for twenty-four hours can be resistant to wind and gravity and often will not be fully dislodged even by violent shaking.

A study (Japan, 1952) cited by Miller (1964) indicates that snow loads on foliage are less at lower temperatures than at temperatures near freezing. Kuriowa (1962) and Minsk (1961) have shown that adhesion is temperature dependent and increases as temperature rises toward freezing. Hoover and Leaf (1966), on the other hand, report that low air temperatures correlated with maximum interception retention. Temperatures from -10° to +21°F. resulted in greater interception retention than did higher temperatures. In this study, however, snowfall occurred in the relatively warm month of April when the amount of interception was less and it was retained for a shorter period of time. Hoover and Leaf (1966) suggested that rimming might be responsible for adhesion rather than high temperatures. Rimming is an important factor on certain areas on the Flathead. No mention is made, however, of other factors such as relative humidity, amount of sunlight of storm intensity and duration of retention. If the lower temperatures are accompanied by a storm of low intensity and long duration, interception retention may be greater than if the temperatures are higher but accompanied by a short duration storm of high intensity.

Once snow has started to accumulate on the foliage, the duration of retention depends largely on the amount of solar radiation incident upon the canopy. If a cloud cover is present, there may not be sufficient diffuse radiation to cause evaporation or mass transport of the snow from the canopy. As the cloud cover is dissipated, the effect of the solar radiation is dependent, in part, upon the characteristics of the intercepted snow. Solar radiation in the winter on the Flathead is quite low and may not provide enough energy to cause evaporation.

Sellers (1965) reports a fresh snow albedo on a bare or open area to be .75 to .95 while the old snow albedo ranges from .40 to .70. Reifsnyder and Lull (1965) state that snow has the highest albedo in nature. Miller (1955) determined that the albedo of one-day old snow varied little with the season and region and had an average value of .84 with a standard deviation of .03. Miller (1962) also stated that intercepted snow in a canopy can reduce effective radiation by fifty percent when compared to a snow-free canopy. Leonard and Eschner (1968) took albedo readings from a tramway above a conifer canopy. Their findings indicated that the albedo was usually less than .20, which tends to refute the generally accepted suggestion that intercepted snow has a high reflectivity.

Anderson's (1956) study was concerned with snowpack accumulation in relation to various cutting practices, the results of which might be applied to interception problems. The study indicated that maximum accumulation occurred where there was sixty-five percent shading and forest openings extended to the north. In comparing the effects of shading from trees on the south with radiation effects from trees on the north, it was found that shade was about twice as effective in preserving the snowpack as the radiation was in reducing the pack. It may follow that if intercepted snow were subjected to significant amounts of shade, it could remain on branches longer than exposed snow.

These studies all seem to indicate that the amount of solar radiation incident upon the canopy and the albedo of the canopy are important factors in determining the final disposition of the intercepted snow. It is generally agreed that the albedo of snow on the ground is quite high and Miller (1962) feels that the albedo of intercepted snow in the canopy is also high. If Miller's (1962) suggestion is correct, there may not be sufficient energy to facilitate evaporation or removal of snow from the canopy. Results for Leonard and Eschner's (1968) study indicate, however, that more research on the albedo of intercepted snow is needed before conclusions can be drawn.

This study does point out the problems encountered in obtaining data on intercepted snow. The low albedo obtained could be due to a number of factors which were not considered in the study. For example, depth of snow on the canopy was judged to be approximately 100mm, which is a relatively thin layer compared to the average snowpack found in the western United States. There was also some mass movement of snow which exposed bare foliage and further reduced the albedo.

Wind Effects on Interception

It has often been observed that snow accumulation is greater in the openings than in the adjacent forest stands. Some observers attributed this difference to sublimation of intercepted snow and concluded that the difference between snow depth in the opening and snow depth in the forest represented the amount of interception loss caused by forest canopies. This difference, however, may be related to a differential deposition of snow in the openings during the precipitation events or a result of wind and aerodynamic relationships between the forest and adjacent openings. Jaenicke and Foerster (1915) found no consistent relationship between the amount of snowfall in an opening and snowfall in a forest. They observed that snow was evenly distributed in the opening and unevenly distributed in the forest.

Miller (1964) cites several studies in which interception was greater at the forest boundaries and on the slopes than in the forest center and on level ground. It was suggested that the difference was due to differential deposition, however, the amount of snow intercepted by the canopy due to wind effects alone cannot really be determined. Falling snow on a forest is often deposited in larger amounts on the windward side of an opening which results in some deficit on the leeward side of the forest (Anderson and Gleason, 1959). Snow density and surface characteristics of the intercepting media are involved in the interception process. According to Russian and Finnish papers cited by Miller (1964), under relatively high wind conditions, the interception of wet snow is greater than dry snow. This would be a logical conclusion since wet snow tends to be more adhesive than dry snow. Hoover and Leaf (1966), however, found little evidence of snow adhesion on conifer foliage. Rather, accumulation began when snowflakes came to rest at the base of needles. Under windy conditions most snowflakes bounced off the needles and did not slide down to the base.

In the Russian and Finnish studies (Miller, 1962) accumulation took place in high steady winds where the snow was literally "plastered" to the trees. In the Hoover and Leaf (1966) study, there was considerable cold air drainage at night and gusty, turbulent winds during the day, which prevented snowflakes from coming to rest on the needles. Miller (1964) pointed out that the angle of delivery of snow to the forest canopy may affect retention as much as the rate of delivery. Wind approaching at a low angle will contact more canopy surface area than a wind with a high-approach angle and may result in greater interception. Thus, a low wind veolcity may increase interception rates while a high wind velocity will probably cause less snow to be retained by the canopy. Maximum snow accumulation in the crowns will probably occur at low wind speeds with temperatures near 32°F. (Miller, 1964).

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The original source of energy is direct short-wave solar radiation. Witherspoon and Ayers (1958) found a direct correlation between high intensity solar radiation and peak runoff and suggested that runoff from the snow melt depends largely upon solar radiation as the energy source. The amount of short-wave radiation reaching a point on earth is dependent upon many variables, such as cloud cover, latitude, region, and season of year. The U. S. Weather Bureau (1964) has tabulated average daily amounts of radiation by month for season and regions of the country. The low, for example, in 1964, was 125 langleys per day for the Northeast during the winter; while the Southwest was high during the summer months with 700 langleys per day. In the Southwest, the mean values for December through April were 250, 275, 375, 500, and 600 langleys per day respectively. It would appear that there is sufficient energy available to support melt and evaporation from snow in the Southwest in winter months. Miller (1962), however, suggested that solar radiation is not sufficient during the winter months for the Central Sierra Nevada Mountains of California to support significant snow evaporation. Miller estimated that, with the amount of energy available, a maximum of 0.7mm water equivalent per day could be lost to evaporation. This same principle probably applies to the Flathead, where available energy in the winter is low.

The net effect of incoming solar radiation is dependent upon the absortivity and reflectivity of the receiving surface. As mentioned above, the albedo of snow is generally considered to be quite high. Leonard and Eschner (1968), however, have suggested albedo values less than .20 for a snow-covered forest canopy. Gerdel (1948) found that the depth to which radiation penetrated a snowpack increased as snow density decreased. If ice and slush were present in the snow, the albedo was decreased with a corresponding increase in radiation absorption. This resulted in a reduction in the amount of radiation transmitted through the ice and slush layer to the lower horizons in the snow.

Goodell (1966) suggested that the mere existence of snow indicates conditions of low evaporation rates. With short-wave albedos of .60 to .80, available energy and vapor pressure gradients necessary to cause evaporation are severely limited. Martinelli (1960) found that summer evaporation losses from alpine areas were probably balanced by condensation. Seasonal evaporation rates in the Sierra Nevadas were found to vary with the topographic exposure and density of forest cover (West, 1962). Goodell (1963) suggested that evaporation from intercepted snow was greatly limited by a lack of energy required to vaporize snow. Although sufficient energy may be available for evaporation, the distribution of radiation, the surface roughness, and the characteristics of the snow may combine to prevent significant evaporation from occurring.

Snow, which has a high albedo for short-wave radiation, is almost a perfect absorber for long-wave radiation (Reifsnyder and Lull, 1965). Conversely, the forest is a slightly better reflector of long-wave radiation and deters long-wave radiation at night upon the snowpack (Anderson, 1963). The net effect of long-wave radiation on snow in the canopy will be determined by the temperature on the snow surface and the leaves as well as the amount of forest cover. Miller (1966) states that the long-wave energy flux from clouds to the intercepted snow is probably larger than the short-wave radiation at almost every location. Long-wave radiation is greatest during the snow storm and decreases rapidly after the clouds dissipate and the air becomes colder and drier. The quantitative effect of this long-wave radiation on newly deposited snow is not known.

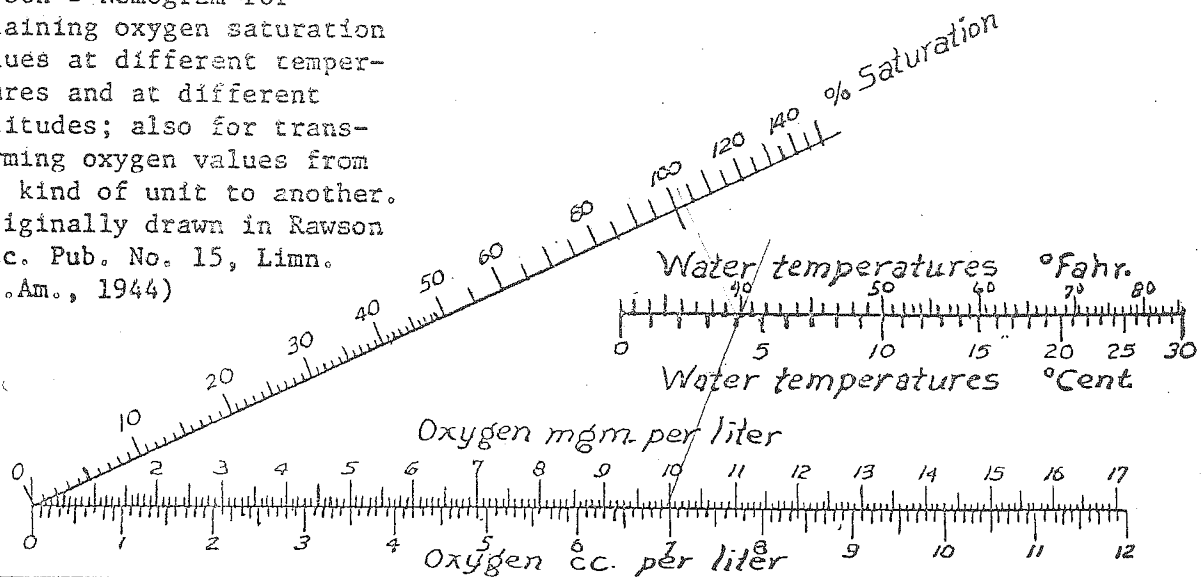
A study to determine the effects of long-wave radiation on snow melt in a forest would be of great value. While quantitative data are not available, we can make some assumptions concerning long-wave radiation. Due to energy available from long-wave radiation, bare foliage surfaces begin to appear in the canopy. These bare areas, with a relatively low albedo, absorb more short-wave radiation, thus increasing melt rates of the intercepted snow. Energy from long-wave radiation becomes more important as the amount of bare foliage surface becomes larger. In a relatively discontinuous canopy, long-wave radiation is utilized by adjacent trees, while in a smoother canopy, long-wave energy may be lost to the atmosphere.

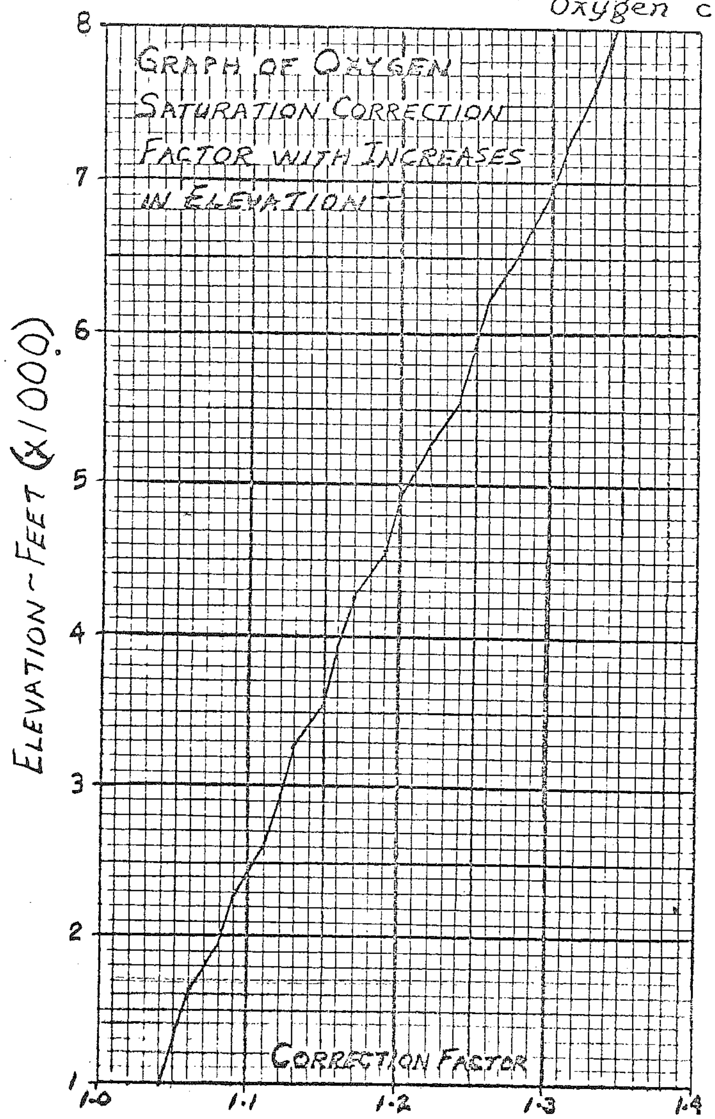
Another major energy source for removing intercepted snow is sensible heat. If conditions exist where air is warmer than the snow layers, there is some energy transfer from air to snow due to turbulence. Satterlund and Eschner (1965) pointed out that even if no temperature gradient exists, there will still be vapor movement from snow to air if a vapor pressure gradient is present. As the vapor leaves the snow layer, the snow surface cools, thereby creating a temperature gradient. The whole system then cools until both the temperature gradient and the vapor pressure gradient are in equilibrium.

From Sverdrup's equations for turbulent heat and vapor transfer to or from a snow surface, Satterlund and Eschner (1965) have calculated that differences in roughness parameters between the forest canopy and the open field are probably the best factors to consider in the determination of evaporation differences between the two areas. They concluded that, if the other elements of the equation remain constant, the effects of surface roughness can be significant. This difference in evaporation rates is due, in part, to the greater transfer of sensible heat in a forest canopy situation.

Evaporation, while easy to explain on a theoretical or mechanical basis, is difficult to determine quantitatively. A vapor pressure gradient must be present for evaporation to take place. The presence of this gradient is due, partly, to wind veolcity, temperature of air and snow and the moisture content of the air and snow. There must also be sufficient energy available to promote the evaporation process. This energy is dependent upon short-wave radiation, long-wave radiation and advected sensible heat. The efficiency of this energy distribution is, in turn, dependent upon surface roughness and albedo. The entire interception-evaporation process is complex and the determination of evaporation rates from the snow intercepted by a forest canopy is difficult. Research techniques are needed that will permit quantitative measurements to be taken from the intercepted snow while it is still on the canopy.

Rawson's Nomogram for obtaining oxygen saturation values at different temperatures and at different altitudes; also for transforming oxygen values from one kind of unit to another. (Originally drawn in Rawson Spec. Pub. No. 15, Limn. Soc. Am., 1944)





INSTRUCTIONS

1. Using Graph of Oxygen Saturation Correction Factor with Increase in Elevation determine the Correction Factor for the elevation at which the oxygen sample was collected.

2. Multiply the Correction Factor by the observed dissolved oxygen content of the sample.

3. With a ruler or dark thread connect the observed temperature on the upper scale with the corrected dissolved oxygen content on the bottom scale.

4. Read the corrected Dissolved Oxygen Saturation Percent at the point where the connecting line crosses the middle scale.

W.L.R., Jr.
October 1971

SECTION III

DEBRIS BASIN and CHANNEL CROSS SECTION MEASUREMENT WITH THE SAG TAPE SYSTEM

TABLE OF CONTENTS

LIST OF FIGURES

DEBRIS BASIN and CHANNEL CROSS SECTION MEASUREMENT WITH THE SAGGED TAPE METHOD

The Sagged Tape Method of channel cross section measurement, developed by C.A. Shumway, is a simplified method for measuring and recording changes in stream channel cross-sections. Previously on the Nezperce these measurements involved the use of surveying equipment, 2-3 men and considerable time and effort. The Sagged Tape technique requires only a steel engineers tape or chain, a measuring rod, a small spring scale and tape clamp, a data form, and can be conducted by one man in about 1/5 of the time required for the old level-rod method. This method is presently used by the Watershed personnel to measure sediment volumes in the Horse Creek debris basins. It is also well suited for use in measuring channel changes over time at selected cross sections in conjunction with the Stream Channel Condition Survey procedures. The collected data, recorded on special forms, is analiyized and processed with an existing computed program. The program is designed to calculate sediment volumes as in a series of transects in a sediment basin, and provide an actual printout of the measured cross section for year to year comparison.

Equipment Needed

1. Steel Tape or Chain. A 50' or 100' reel tape is normally used. It will be necessary to determine the weight in pounds for a 1 (one) foot section of the tape. This data is required for the computer analysis program. The S.O. Watershed Lab. is equipped with a precision electronic balance that can be used to determine this data.

2. Measuring Rod. Any device is suitable which can be used to measure the distance in feet and tenths of feet from the tape to the channel bottom.

The bottom half (0 to 6' section) of an old surveyors rod is used in Horse Creek. A standard U.S.G.S. wading rod or a steel pocket-tape scaled in feet and tenths are convenient for shallow depths.

3. Tension Scale. This item is simply a small, pocket sized, spring scale that is used to measure the tension applied when stretching the tape between the two stakes of the transect or cross-section. Such a scale is inexpensive and may usually be purchased at most hardware stores. The scale should have a capacity of 20 to 30 lbs. A regular tape tension scale is available from the K&E Co.; described as a "Tape Tension Handle", 30 lb. English and 15 Kg. Metric, Cat. No. 89-1071.

4. Tape Clamping Device. The most suitable item we have used to date to hold the stretched tape in tension is a "vice-grip" type of locking pliers with a "spoon-bell" modified nose. For a specific description of this piece of equipment and an equipment set up see Figures A and E.

5. Stake Fasteners. A locally constructed item that slips over the transect stake to provide a fastening point for the engineers tape and tension scale. See diagram in Figure A.

6. Transect or Cross Section Stakes and ID Tags. Two metal stakes, 18 to 24 inches in length, of 3/8 to 5/8 "re-bar" material are best suited for permanent locations. A metal "nursery" tag or metal tape is used to identify each transect with a number or ID code.

7. Data Forms. A reproduceable copy of the required data record form is shown on Figure D, along with a form showing sample data required for card punching and processing; Figure C.

PROCEDURE

1. Establishing Cross-Sections

Generally the cross-section locations are predetermined with respect to the drainage in which they are to be established. Where a series of cross-sections are to be established as in a debris basin or stretch of unstable channel, the only requirement is that the cross-sections are parallel; with the distance between each section known. The distance between cross-sections may be a fixed interval, or the distance can vary from one section to another, as long as all sections are parallel. The only other requirement in establishing cross-sections, other than being parallel, is that the top of the stakes at the ends of a given cross-section be nearly on the same level with each other. A string-line level or Abney Level is adequate for meeting this requirement.

2. Measurement

Once the cross section is established, the steel tape or chain is stretched from the top of one of the cross-section stakes to the tape clamp and spring scale, which is attached to the other stake. See Figures A andB. Tension is applied to the tape, as the tape is drawn up and clamped. The tension shown on the scale must be at least 5 pounds, plus one pound for each 10 feet of transect length; ie. stake to stake distance. The computer will correct for depth errors due to tape sag if it is given the weight of the tape in lbs/ft.; the length of the transect or cross-section, and the tension in lbs. on the spring scale.

Depth measurements are taken from the tape to the ground surface or channel bottom and recorded in feet and tenths. The first and last measurements are always taken at the cross-section stakes. Measurements may be taken along the tape at fixed intervals, or at any interval desired to show changes in the existing ground surface or channel bottom. It is important to remember the computer does not know the shape of the cross-section, but reconstructs it from measurement data as though it were a series of straight line segments between the cross-section stakes. Note the dashed lines in Figure B. Therefore, the surveyor should take care to perform sufficient depth measurements to adequately describe the cross-section profile.

3. Survey Forms

An example of a survey form with data entered is shown as Figure C. Each form entry under columns 21 through 77 must contain the specified number of digits as indicated by the "X"s at each column heading. "Leading" zeros must be used if necessary to complete the proper number of digits.

The understood location of the decimal point is shown in the tape tension and depth columns, but is not to be written with each entry; ie. a depth measurement of 3.6 feet would be entered as 036. Note: Depth measurements are always taken in feet and the nearest 1/10 foot while distance along the tape at the points of measurement is recorded to the nearest foot.

Heading Notes:

Region: Enter 01

Forest: Enger Nezperce

PWI W/S No: The first ten digits of this number will be the designated Project Work Inventory Watershed Number shown in FSM 2573.5 for the area in which survey is made. The specific sub-basin or drainage is designated by the last two digits, which are obtained from the PWI subdrainage map in the District Water Resource Atlas.

Observers: Enter last name or names.

Identification: Up to 80 columns or letter spaces are provided for more specific descriptive information concerning the location of the transect, ie. District, subdrainage, etc.

Date: Enter month, day and year with lead 0's if necessary.

Basin Name: 12 columns, usually used to show mane or ID of PWI Watershed or larger subbasin.

Basin Area: Enter Area in square miles to nearest 100th. This data is important when surveying a sediment or debris basin with a series of transects, as the computer will provide a print-out of sediment yield in tons per sq. mile, cubic yds. per sq. mile, etc.

Tape Weight: Enter the weight of a 12" section of the tape used in the survey; in <u>pounds per foot</u>. It is suggested that once this number is determined, it should be etched into the tape reel and tape leader.

Compare Code: Leave blank unless the survey now being taken will be compared with a previous survey. When a comparison is desired for a present survey with an earlier survey, enter <u>01</u>.

<u>Cross Section, Columns 21-29</u>

Type: Enter 1 for the first cross-section of a basin;
Enter 2 for the last cross-section of a basin;
Enter 9 to denote the end of the basin survey.

Sta. No.: Enter a four digit series with lead 0's if required. In the case of the sample form (Figure C) where selected channel condition stations were surveyed, enter the number of the station as shown.

If a debris basin or sediment dam is being surveyed, enter the cumulative distance in feet between the parallel sets of transects. In this case the starting set of stakes would have a Sta. No. of 0000. If the next set of stakes were 4 feet upstream, their Sta. No. would then be 0004. A third set of stakes 4 feet further upstream would have a Sta. No. of 0008, etc.

Correction Code: This field is provided for the purpose of adding, deleting, or moving cross-sections if required. No entry or a blank indicates a normal cross-section. Enter 1 to indicate an added cross-section. Enter 2 to indicate preceeding cross-section moved. Enter 3 to indicate cross-section to be removed.

Points of Measurement, Columns 30-77

Dist: Enter 000 as distance for first measurement at pin. Enter distance to nearest foot for succeeding measurement points along tape; ie., at 23 feet enter 023, etc. The last Dist. entry for a transect should represent the total transect length, to the nearest foot.

Dep: Enter depth measurement from tape to ground surface or channel bottom, in feet and nearest tenth of a foot; if the measured depth is 1.2 feet, enter 012 without the decimal point. For those cross-sections which have more than 8 Points of Measurements, continue on the nest line, starting in column 30. Enter 999 under Dist. and 999 under Dep. to indicate the end of a particular cross-section data.

FIGURE A. (Sag Tape System)

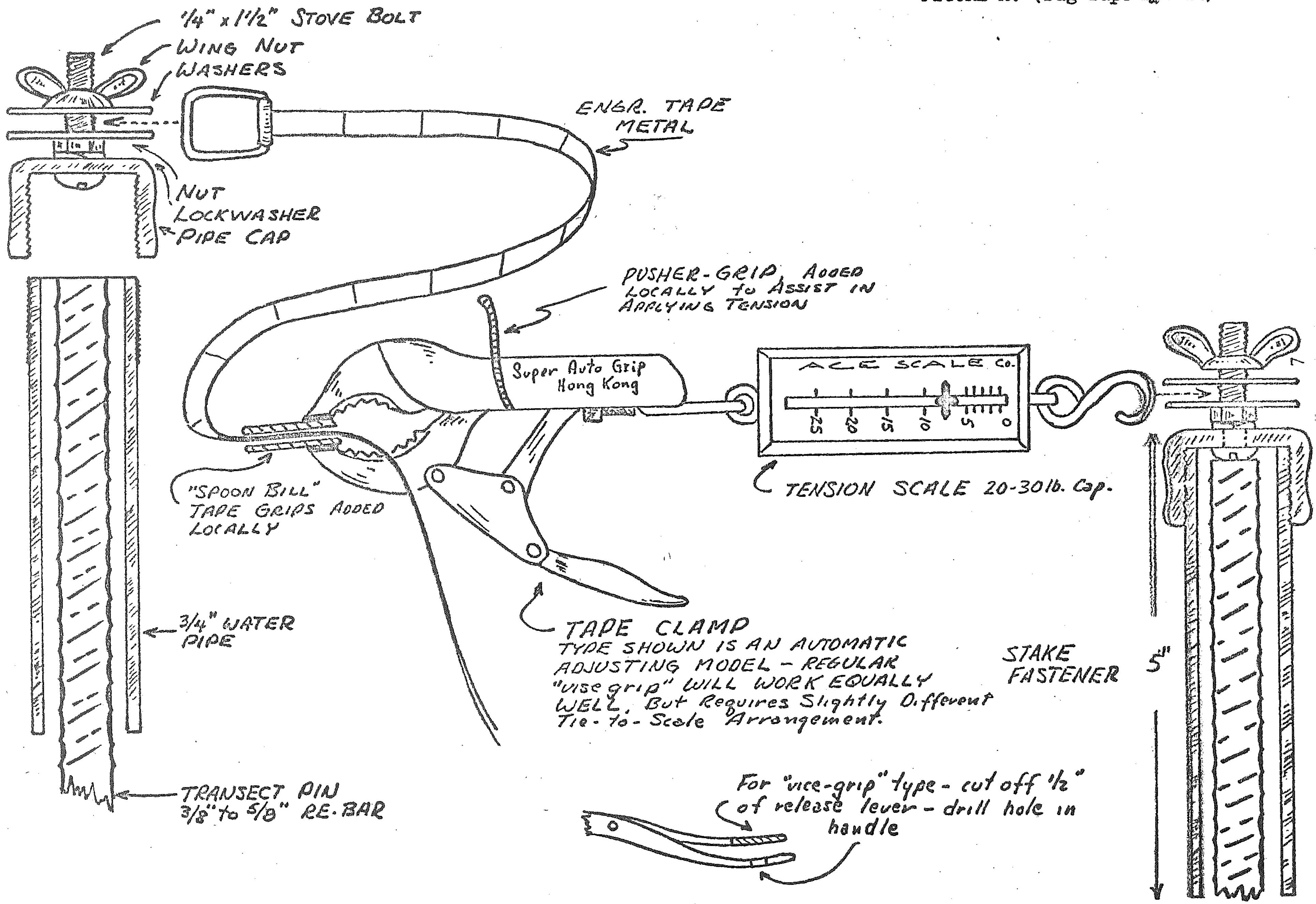
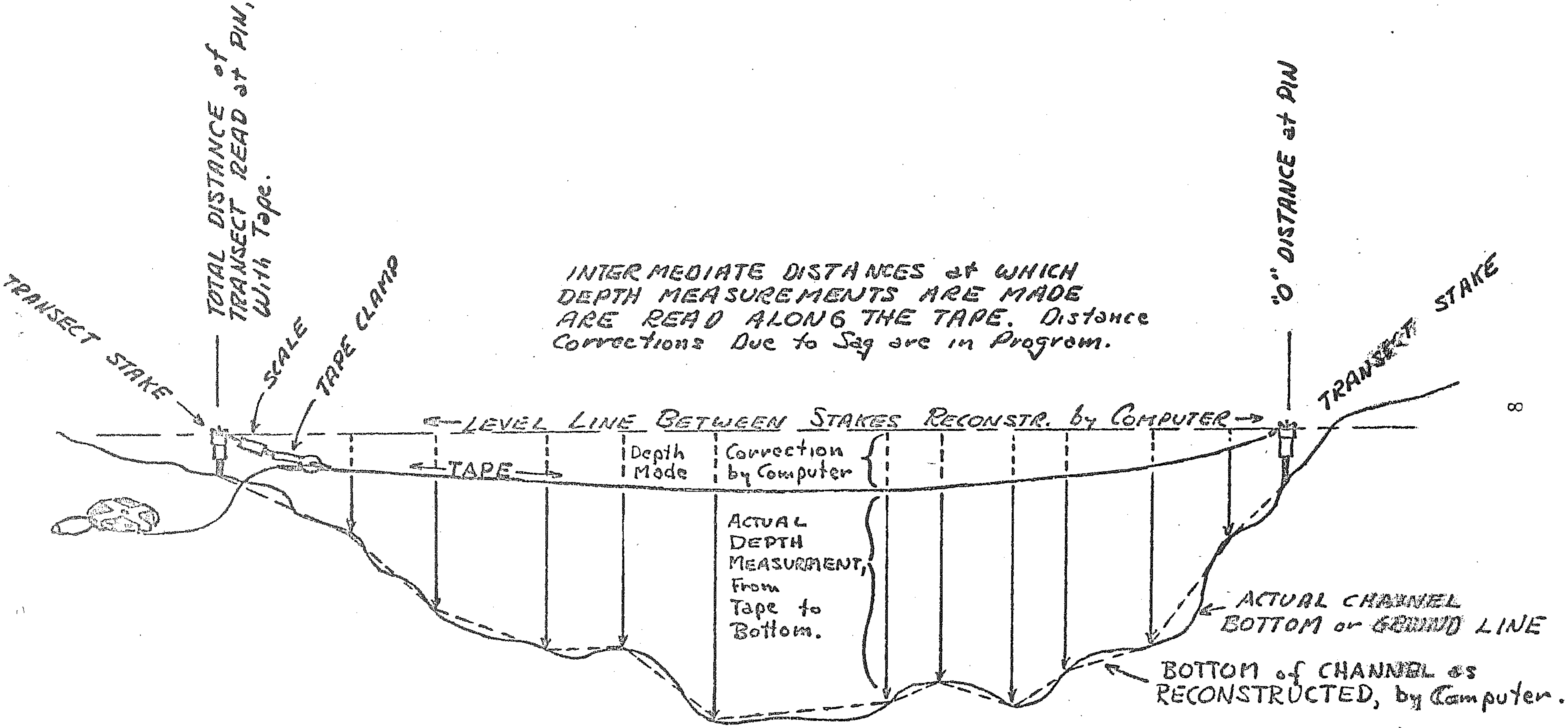


FIGURE B. (Sag Tape System)



DEBRIS BASIN MEASUREMENT RECORD - Sag Tape System FIGURE C. (Sag Tape System)

ion: 01 Forest: NEZPERCE PWI W/S No. 16 - 14 - 23 - 00 - 08 - 09 Observers: Smith & Jones

ntification: (1-80 col. as needed) South Fork Cow Cr. at Channel Survey Sta 1, 3, 7, 9, Subdrainage III

th 07 Day 14 Yr. 72 Basin Name: S _ FK _ COW _ CR _ (12 col.)

n Area 03 . 52 Sq. Mi. Tape Weight: .0064 lbs./ft. Compare Code: --

Cross Section				Points of Measurement															
e	Sta. No.	Corr Code	Tape Ten. lbs.	1		2		3		4		5		6		7		8	
				Dist	Dep	Dist	Dep	Dist	Dep	Dist	Dep	Dist	Dep	Dist	Dep	Dist	Dep	Dist	Dep
	XXXX	X	XX.X	XXX	XX.X	XXX	XX.X	XXX	XX.X	XXX	XX.X	XXX	XX.X	XXX	XX.X	XXX	XX.X	XXX	XX.X
	22-25	26	27-29	30-32	33-35	36-38	39-41	42-44	45-47	48-50	51-53	54-56	57-59	60-62	63-65	66-68	69-71	72-74	75-77
	0001		135	000	008	002	011	003	014	006	015	008	021	010	024	014	028	016	022
				019	018	022	013	026	009	028	007	029	004	999	999				
	0003		141	000	004	004	006	008	009	010	012	012	018	014	022	016	016	020	010
				024	008	028	003	999	999										
	0007		120	000	006	002	010	004	016	005	024	006	019	008	011	012	008	014	004
				999	999														
	0009		151	000	010	004	015	008	016	010	020	012	014	016	007	021	006	999	999

s: 1) For Cross Sections exceeding Pt. of Measr. #8; continue in col. 30.
2) Type code (col. 21): 1 = First X-section of basin; 2 = Last X-sec. of basin; 9 = End of basin survey.
3) Enter 999 in Dist Column followed by 999 in Dep column to denote end of cross section data.
4) Correction Code: Blank = Normal X-sec; 1 = added X - sec; 2 - preceeding X-sec. moved; 3 = X-sec. to be removed.
5) Tape Tension: reading should be at least 5 lbs. plus 1 lb./ea. 10' of X-sec. width, not to exceed 30 lbs.
6) It is unnecessary to enter decimal point in Depth Col. data; i.e., 4.2 feet would be shown as 042.

DEBRIS BASIN MEASUREMENT RECORD - Sag Tape System

FIGURE D.(Sag Tape System)

;ion: ___ Forest: ______________ PWI W/S No. _ _ - _ _ - _ _ - _ _ - _ _ - _ _ Observers: ________

entification: (1-80 col. as needed) ______________________________

ıth _ _ Day _ _ Yr. _ _ Basin Name: _ _ _ _ _ _ _ _ _ _ _ _ (12 col.)

ıin Area _ _ . _ _ Sq. Mi. Tape Weight: ._ _ _ _ lbs./ft. Compare Code: _ _

Cross Section				Points of Measurement															
				1		2		3		4		5		6		7		8	
›e	Sta. No.	Corr Code	Tape Ten. lbs.	Dist	Dep	Dist	Dep	Dist	Dep	Dist	Dep	Dist	Dep	Dist	Dep	Dist	Dep	Dist	Dep
‹	XXXX	X	XX.X	XXX	XX.X	XXX	XX.X	XXX	XX.X	XXX	XX.X	XXX	XX.X	XXX	XX.X	XXX	XX.X	XXX	XX.X
	22-25	26	27-29	30-32	33-35	36-38	39-41	42-44	45-47	48-50	51-53	54-56	57-59	60-62	63-65	66-68	69-71	72-74	75-77

es: 1) For Cross Sections exceeding Pt. of Measr. #8; continue in col. 30.
2) Type code (col. 21): 1 = First X-section of basin; 2 = Last X-sec. of basin; 9 = End of basin survey.
3) Enter 999 in Dist Column followed by 999 in Dep column to denote end of cross section data.
4) Correction Code: Blank = Normal X-sec; 1 = added X - sec; 2 = preceding X-sec. moved; 3 = X-sec. to be removed.
5) Tape Tension: reading should be at least 5 lbs. plus 1 lb./ea. 10' of X-sec. width, not to exceed 30 lbs
It is [illegible] to enter decimal point in Depth Col. data, i.e., 4.2 feet would be shown as 042.

Components and Arrangement of Sag Tape Kit
(photos - following page)

FIGURE E. (Sag Tape System

1. <u>Pipe - Tape Support</u>: Slides over transect stake; constructed locally from 3/4 inch water pipe, pipe cap, 1/4 x 2 inch stove bolt with nut, and series of washers which act as a "bearing" and clamping surface for the tape end, and wing-nut.

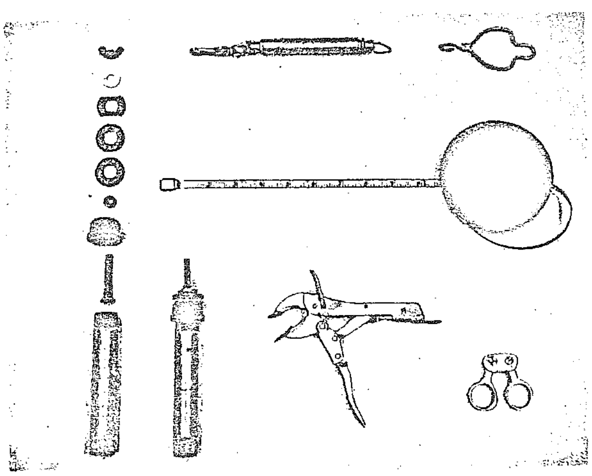
2. <u>Scale</u>: Item shown is a "K&E" Tension Handle, #89-1071, 30 lb. or 15 kg. capacity.

3. <u>Wire Handle for Scale</u>: Designed locally from #9 phone wire, to fit readily over pipe-tape support.

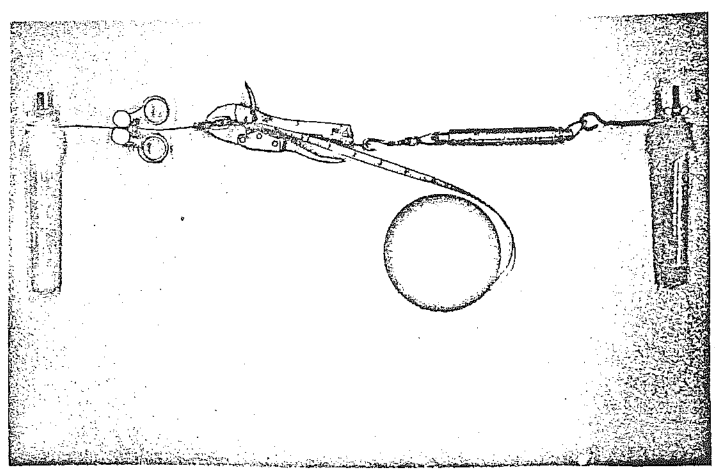
4. <u>Gripping Pliers</u>: Item shown is a 6 inch "Leversrench", automatic adjusting for tension or jaw pressure, manufactured by "Leverwrench" Tools, Inc., Glenvil, Nebraska 68941. A "vicegrip" type pliers works equally well.

5. <u>Clamping Handle</u>: From K&E, #89-1098, for pulling up steel tapes, especially when working in cool weather without gloves and tape lengths greater than 15 feet.

6. <u>Tape</u>: Item shown happens to be a K&E product, "Stevens Wyteface A"; 100', #86-0124, with end fastener, and measurements starting at tip of ring on 0 - end of tape.



Components of Sag Tape Kit



Arrangement of Sag Tape Components

Note: The above apparatus was designed to be used in collecting field data for <u>DEBRIS</u> and <u>PLOT D</u> which are computer programs for determining cross sectional areas of stream channels and volumes of Debris collection basins.

SECTION IV

WATER TEMPERATURE CONTROL

U.S.F.S. Region 6

The following information is taken in part from a Region 6 publication entitled "Guides for Protecting Water Quality".

WATER TEMPERATURE CONTROL

CONTENTS

WATER TEMPERATURE CONTROL

INTRODUCTION

One of the impacts of forest land management is an increase in water temperature when shade-producing vegetation is removed.

The greatest source of energy for raising stream temperature is solar radiation. Energy may be lost or gained through evaporation, condensation, conduction or convection, but these processes affect temperature less than solar radiation. Thus, streamside shade is the most important factor influencing changes in water temperature over which the land manager has some control.

By maintaining adequate vegetative cover of such height and density as to adequately shade the stream during periods of maximum solar radiation, water temperature increases can be prevented and/or minimized as necessary to meet management goals.

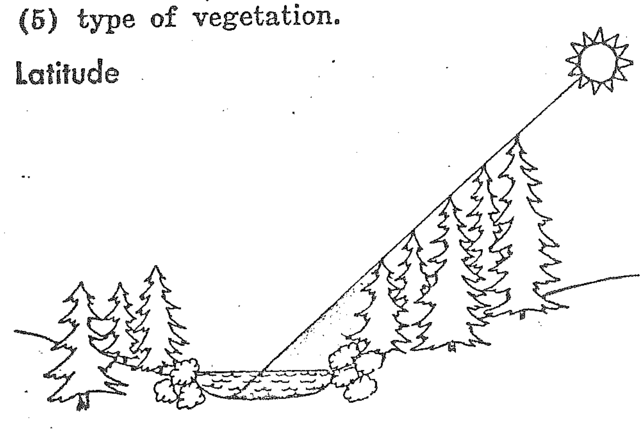
It is not possible to prescribe beforehand how much vegetation should be left. This will vary from site to site.

The objectives of these guidelines are (1) to familiarize the user with some of the factors and influences that should be considered in making an on-the-ground decision on a case-by-case basis and (2) to provide a means for predicting temperature changes.

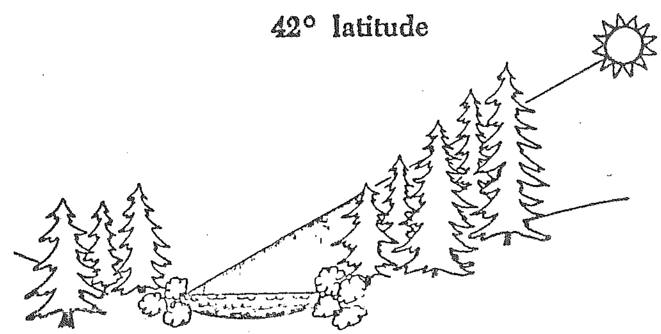
WIDTH DETERMINATION

The width of strip necessary to provide maximum shade will depend primarily on (1) latitude, (2) width of stream, (3) the orientation of the stream, (4) spacing of vegetation, and **(5) type of vegetation.**

Latitude



42° latitude



49° latitude

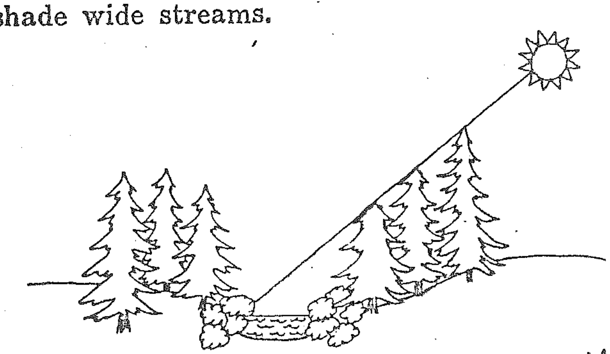
Figure 1

The sun's angle varies with latitude, i.e., the lower the latitude, the greater the angle. Figure 1 illustrates that the same vegetation which effectively shades the entire stream at latitude 49° does not provide full shade at latitude 42° since the sun's angle is greater.

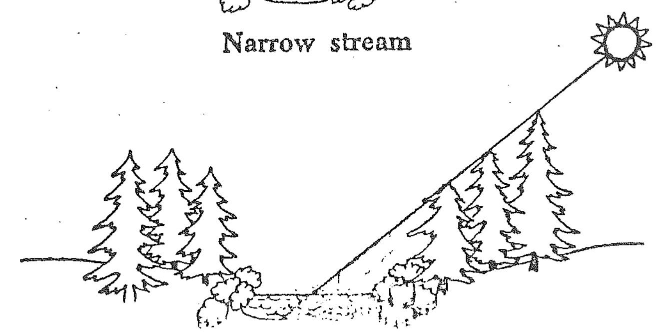
Therefore, at lower latitudes, vegetative cover should be taller to provide adequate shade.

Stream Width

Figure 2 illustrates that the same vegetative cover that fully shades the narrow stream provides only partial shade to the wide stream. Brush or hardwoods can effectively shade small, narrow streams. While on the other hand, conifers or taller vegetation are needed to fully shade wide streams.



Narrow stream



Wide stream

Figure 2

Therefore, the wider the stream, the taller the vegetation needed to effectively shade the stream.

Table 1 shows the height of vegetative cover needed to provide effective shade for various stream widths and latitudes. The data shown are those which occur in mid-July when water temperatures are more likely to be critical.

Table 1

Height of Vegetative Cover Needed to Offer Shade

Stream Width (ft.)	Latitude 42°	Latitude 45°	Latitude 49°
	Height of Cover (ft.)		
2	6	5	4
4	10	9	7
8	21	18	15
12	31	27	23
18	47	40	34
20	52	45	38
30	78	67	56
40	104	90	75
50	130	112	94
75	195	169	141
100	260	225	188

The height of vegetative cover needed for any width of stream and any latitude can be calculated by the formula:

$$\text{tangent } A = \frac{a}{b} \text{ or}$$

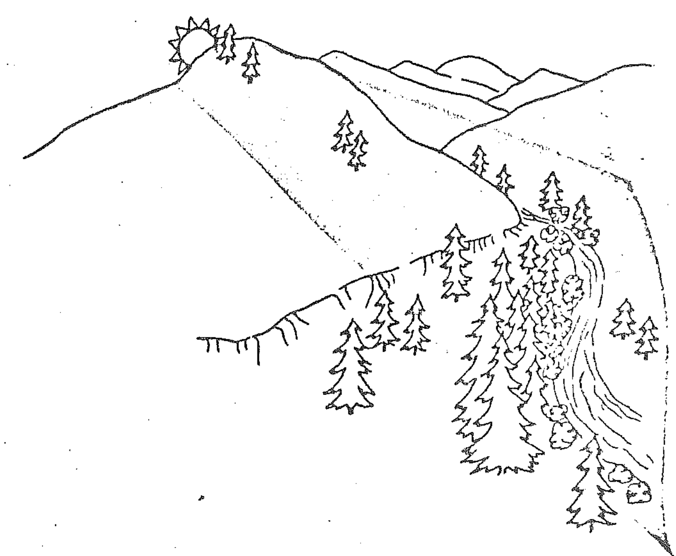
height (ft.) = natural trigonometric function of the tangent of the sun angle times stream width (ft.)

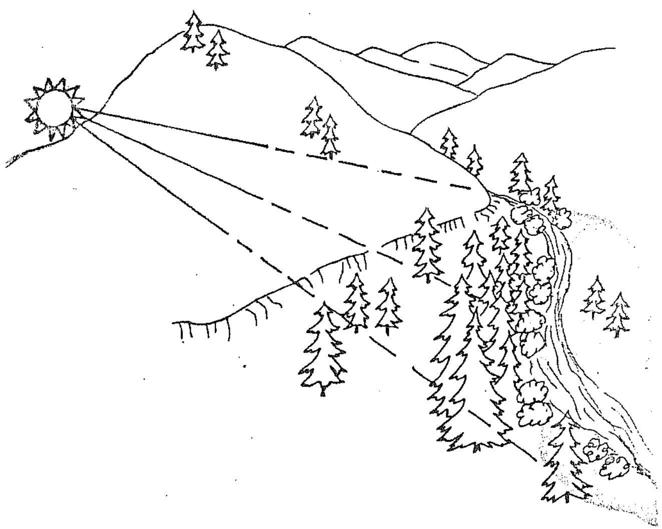
The sun angle for any latitude for any date in question can be calculated by referring to a solar ephemeris to obtain apparent declination and using the following formula:

Solar angle = 90 — (latitude - apparent declination)

Topographic Shading and Orientation

Figure 3 illustrates that at certain times of the day topographic influences on the south side of an east-west oriented stream may be effective in shading the stream without any vegetative cover. However, in the example, as the sun moves across the horizon and away from the topographic influences, vegetative cover on the south side next to the stream then provides the maximum shade.

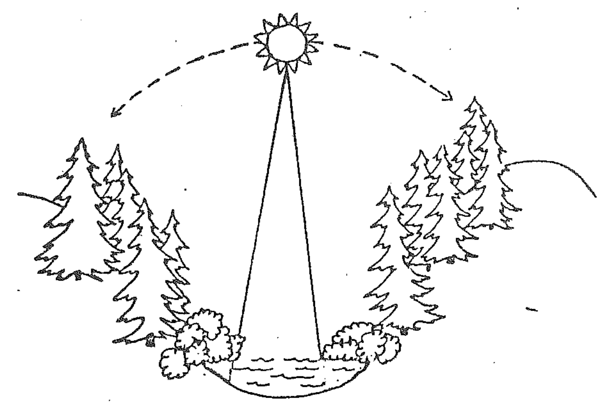




East-west with topographic shade

Figure 3

Figure 4 shows the effect of vegetative cover on north-south oriented streams which illustrates the need for vegetative cover on both sides of the stream. At midday, that vegetation which overhangs or is immediately adjacent to the stream is more effective. Later in the day when the sun's declination has changed, vegetation further from the stream also provides shade.



North-south

Figure 4

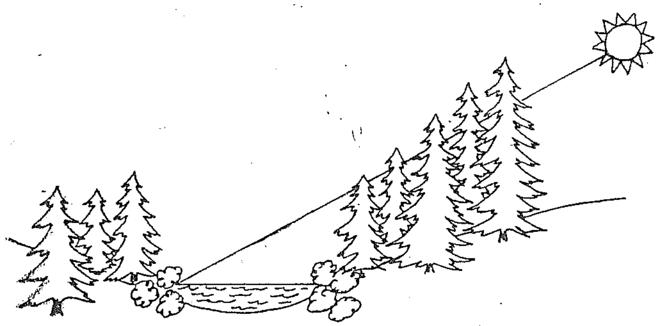
Shade from topography can effectively shade streams.

East-west oriented streams need shade only on the south side of the stream while north-south streams need shade on both sides.

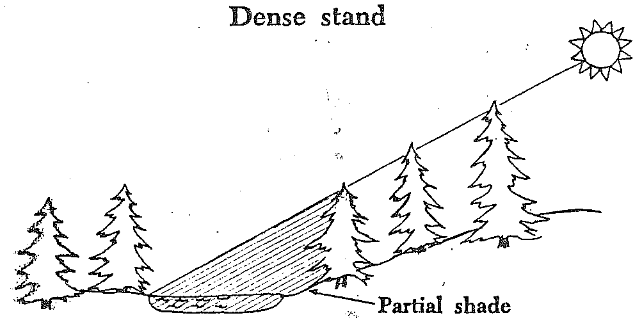
Because streams normally meander in many directions over a short distance, it is usually not practical to maintain vegetative cover only on one side; consequently, cover is normally maintained on both sides of the streams.

Spacing of Vegetation

If vegetation is not spaced close enough, the stream may not be effectively shaded even though the vegetation is of sufficient height.



Dense stand



Widely spaced stand

Figure 5

Figure 5 illustrates that *a dense stand of trees can effectively shade the stream, while a widely-spaced stand of trees allows sun to filter through to the stream.*

Tables 2 and 3, below, show how tree density or stocking affects the light intensity. (Reference USDA Tech. Pub. No. 1344, Radiant Energy in Relation to Forests, Dec. 1965). While light intensity is not the same as solar radiation, the tables do present some qualitative estimate of tree density necessary to provide various degrees of shade. Light intensities will also vary with other factors such as size and species.

Table 2

Stand Density Effects on Light Intensity

	% of Fully Stocked Stand Removed	Light Intensity (% of Open)
Stem Density	0	8
	25	14
	50	26
	75	55
Canopy Closure	0	4
	25	6
	50	16
	75	43
Basal Area	0	10
	25	15
	50	27
	75	52

Example: Removing 75% of the stems would increase the light intensity from 8% to 55%.

Table 3

Spacing Effects on Light Intensities

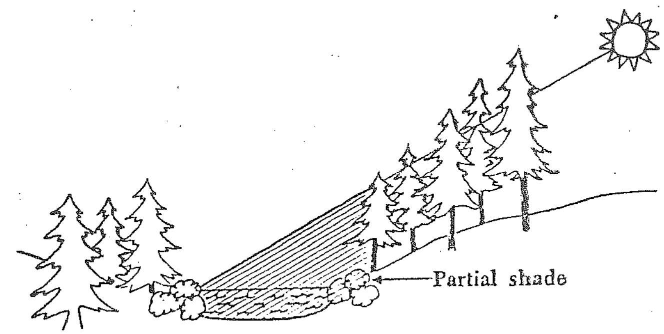
Spacing (ft.)	Trees (*Number/acre*)	Light Intensity (%)
4 by 4	2721	15
6 by 6	1210	16
7 by 7	889	36
9 by 9	538	60

Example: By removing slightly less than half the trees (538) from a 6 by 6 foot spacing (1210) increases the light intensity from 16% to 60%.

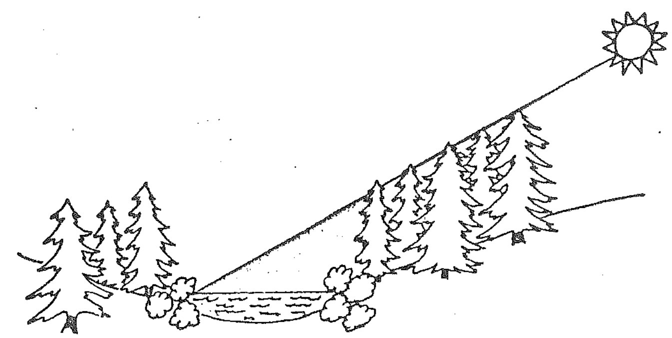
Type of Vegetation

Associated with spacing of vegetation is the type of vegetation. For example, Figure 6 illustrates that a mature stand of conifers, with much of the lower bole free of limbs, may offer only partial shade; whereas a younger, bushy stand of trees may provide more shade. Some species of trees with sparse limbs, such as western larch, may not provide as much shade as white fir.

Understory species, such as hardwoods or brush, generally provide very adequate shade for small streams.



Mature stand



Young stand

Figure 6

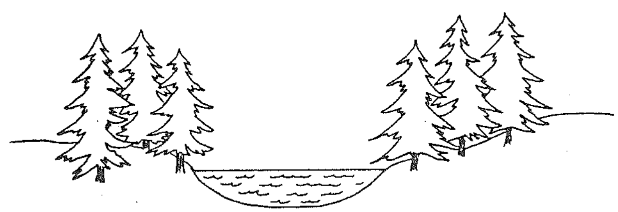
In general, the most efficient shade producers are young, bushy, poor form trees.

STREAM CHARACTERISTICS

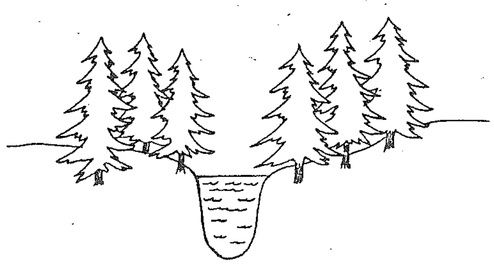
Stream characteristics such as width, volume of flow, gradient, and stream bed characteristics collectively influence the extent any given amount of exposure will affect temperature.

Area and Volume

Temperature change is directly proportional to the area of stream exposed and the duration of exposure, and indirectly to the volume of water.



Wide stream

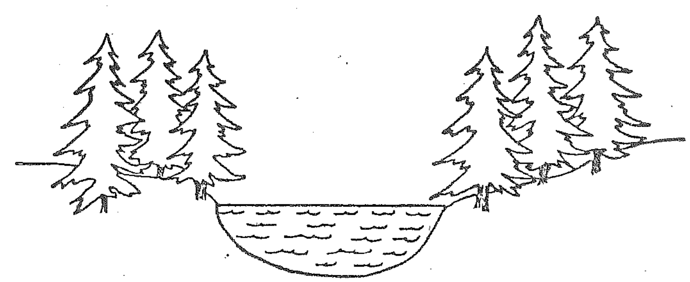


Narrow stream

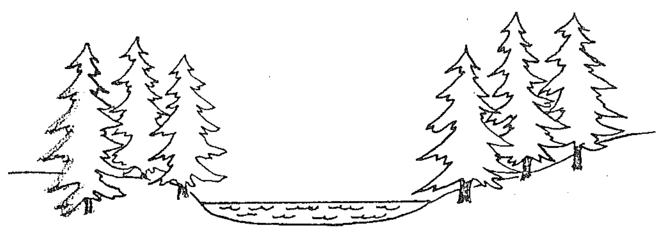
Figure 7

For example, Figure 7 illustrates two streams with the same volume of flow but with different cross-section areas (or widths). The wide stream is three times wider than the narrow stream; therefore, temperature changes for the wide stream would be proportionally greater.

On the other hand, Figure 8 illustrates two streams of equal width, but with a volume of flow for the deep stream three times greater than for the shallow stream. Consequently, temperature change for the deep stream would be proportionally less.



Deep stream

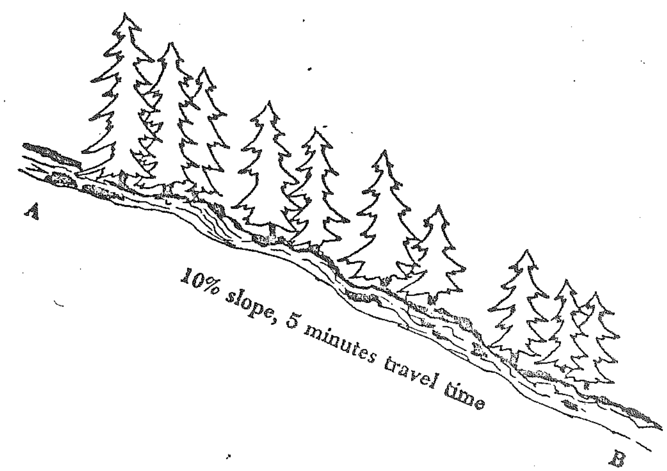


Shallow stream

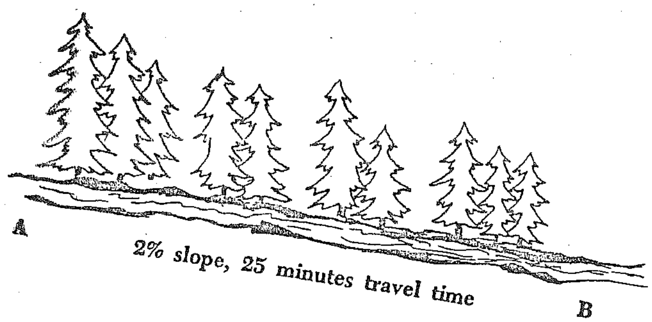
Figure 8

Stream Gradient

Figure 9 illustrates where the water is exposed to the sun's energy for only 5 minutes in traveling from point A to B on the steep gradient stream; whereas, in traveling an equal distance on a low gradient stream, the stream is exposed 5 times longer to the sun's energy. The increase, while not proportional, will be higher for the low gradient stream.



Steep gradient



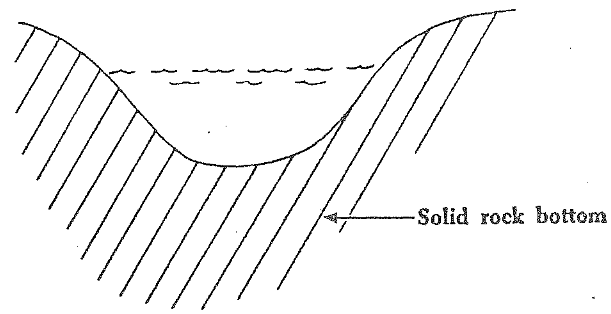
Low gradient

Figure 9

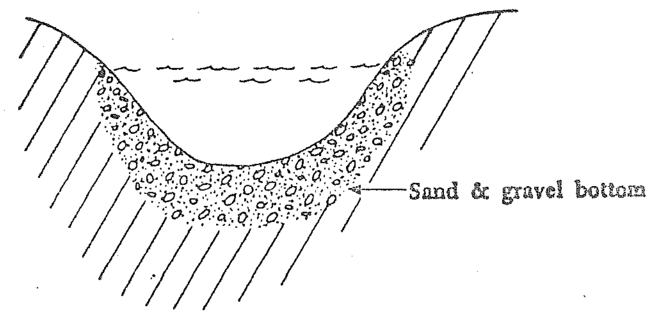
All else being equal, steep, fast-flowing streams heat up less than slow, low gradient streams because the stream exposure time to the sun's energy is less.

Channel Type

The type of stream bottom or channel can have an influence on stream temperature. *As illustrated in Figure 10, solid rock bottoms act as a "heat sink," storing the sun's energy, thereby stream temperature does not heat up as much nor does it cool as rapidly; whereas, gravel, sand, or boulder bottoms will both heat up and cool more rapidly.*



Bedrock



Gravel

Figure 10

PREDICTING WATER TEMPERATURE INCREASES

Reference: Brown, George W., 1970. Predicting the Effect of Clearcutting on Stream Temperature. Journal of Soil and Water Conservation. 25 (1) :11-13.

Temperature Increase Formula

Increases in water temperature can be estimated by the formula:

$$\Delta T = \frac{A \times H}{D} \times .000267 \text{ where:}$$

ΔT = predicted change in temperature (°F)

A = surface area of stream exposed in square feet (length × width)

D = discharge in cubic feet per second

H = amount of heat absorbed in British thermal units per square foot per minute

.000267 = content converting discharge to pounds of water per minute

Field procedure to use the formula can be summarized as follows:

1. Define the upstream and downstream boundaries of the proposed area of vegetative removal.

2. Determine the surface area in this proposed area that will be exposed during maximum solar radiation (A = length × width in sq. ft.) during low-flow conditions.
3. Determine lowest discharge (D) during the period of maximum water temperatures expected and dates when it occurs.
4. Determine the travel time of the stream through the proposed area at low flow.
5. From a solar ephemeris for the latitude in question, determine the highest sun angle at solar noon for the maximum water temperature period.
6. From Figure 12, with the appropriate travel time, determine the average radiation (H).
7. Compute the predicted maximum change in temperature, using the formula.

Mixing Ratio Formula

The above formula can be used to predict what increase might occur on the site. What impact such increases might have downstream can be predicted by the following mixing ratio formula:

$$T = \frac{Dm\ Tm + Dt\ Tt}{Dm + Dt} \text{ where}$$

T = temperature of the main stem after the tributary enters

Dm = discharge of main stem before tributary enters

Dt = discharge of tributary

Tm = temperature of main stem before tributary enters

Tt = temperature of tributary

If the formula is transposed to:

$$Tt = \frac{T(Dm + Dt) - Dm\ Tm}{Dt}$$

it can be used to determine what tributary temperature (Dt) can be tolerated to maintain a desired downstream temperature (T). This can be helpful where temperature standards have been prescribed.

Limitations of the formula

1. Should be limited to short stretches less than 2,000 feet.
2. Cooling ground water inflow is not considered.
3. Difficult to measure discharge and travel time on very small streams with obscure flow patterns.
4. Where streambeds are solid rock some solar energy may be absorbed by the bed resulting in a lower value of heat absorbed (H).
5. On very small streams with obscure flow, measurements of stream width are more critical.
6. The capacity of a stream for absorbing heat is not infinite as other factors become important. As stream temperatures approach air temperatures an equilibrium will be reached. Consequently temperature increases exceeding 20°F or maximum water temperatures over 90°F should normally not be expected for free flowing streams in the Region.

Example

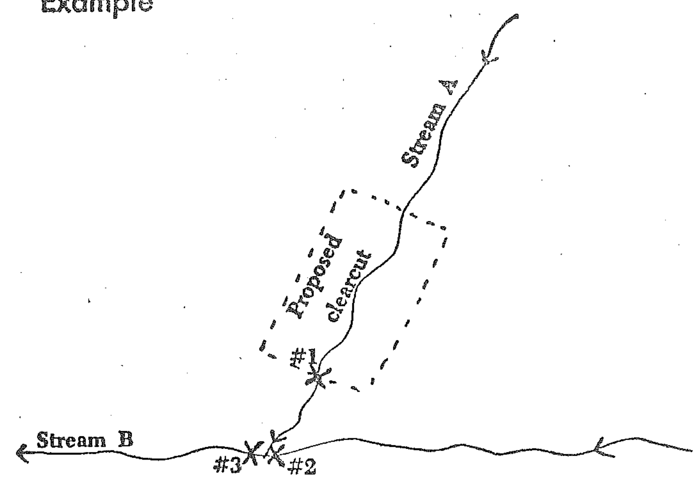


Figure 11

Given:

1. At latitude 43° on August 21 a proposed clearcut will expose 1000′ of stream with an average width of 10′. Travel time for the water to flow through the clearcut is 1½ hours and discharge of the stream at point #1 is 1 cubic feet per second (cfs). Water temperature at point #1 prior to cutting is 60°F.
2. The discharge and water temperature at point #2 is 50 cfs and 70°F.

Problem:

1. Determine what the maximum effect the proposed clearcut will have, if any, on water temperatures immediately below the unit at point #1 and what effect this change will have downstream at point #3. (Assume no change in flow or temperature for Stream A from point #1 to where it intersects Stream B and August 21 is the approximate time water temperature will be most critical).

2. Determine how much increase in temperature for Stream A would raise Stream B at point #3 2°F.

Calculations:

1. *Clearcut Effect*

   Use formula

$$\Delta T = \frac{A \times H}{D} \times .000267 \text{ where:}$$

$A = 1000 \times 10 = 10{,}000$ sq. ft.
$D = 1$ cfs
$H = 4.1$ btu/ft²/min for a solar angle of 59° and a travel time of 1½ hours

$$T = \frac{10{,}000 \times 4.1}{1} \times .000267$$

$T = 11°F$ increase with a resulting temperature at point #1 of 71°F (11° + 60°)

Effect at Point #3

Use formula $T = \frac{DmTm + DtTt}{Dm + Dt}$
where:

$$T = \frac{50 \times 70 + 1 \times 71}{50 + 1}$$

$T = 70°$ (no effect)

2. *Increase necessary to raise stream B 2°F*

   Use formula

$$Tt = \frac{T(Dm+Dt) - DmTm}{Dt}$$

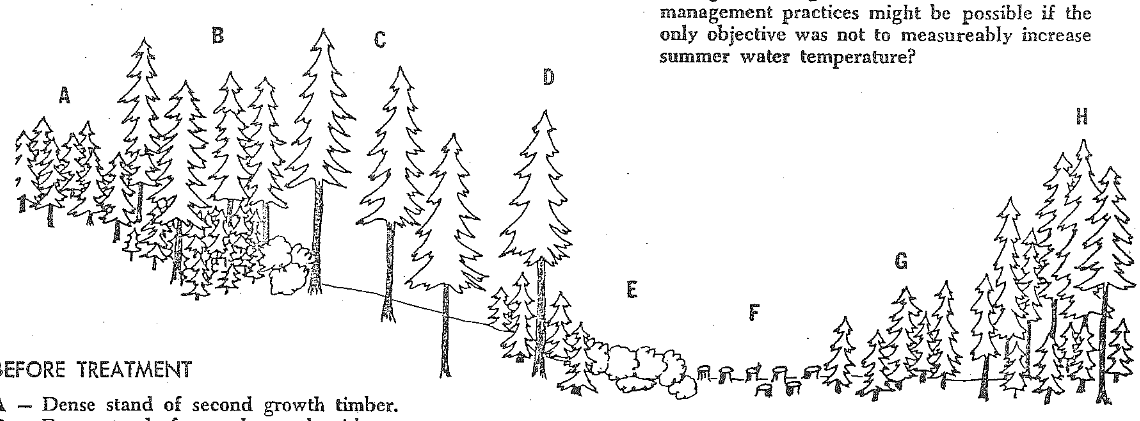
where:

$$Tt = \frac{72° \ (50 + 1) - 50(70)}{1}$$

$Tt = 172°$ or an increase of 112° above the present 60°F to raise the main stem 2°F.

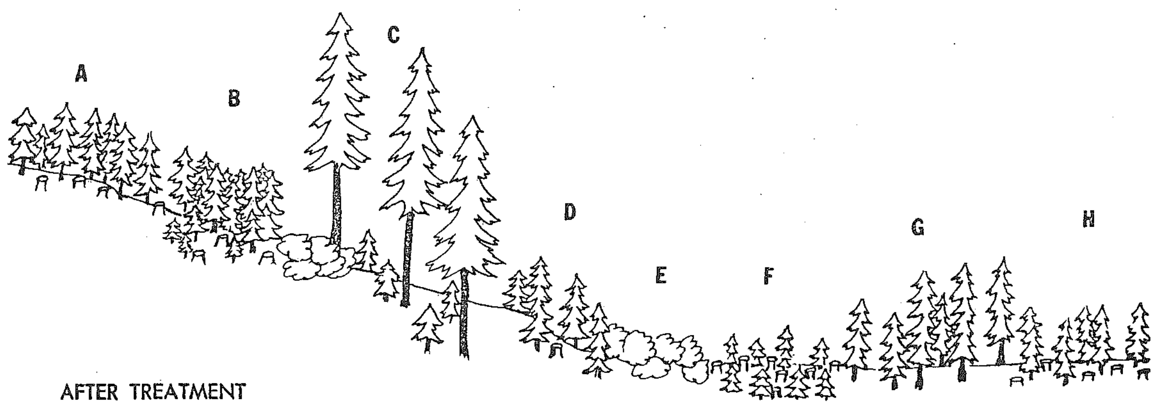
APPLICATION EXAMPLE

EXPLANATION: Assume a small stream flows from point A to H through a homogeneous area as shown. What management practices might be possible if the only objective was not to measureably increase summer water temperature?



BEFORE TREATMENT

A – Dense stand of second growth timber.
B – Dense stand of second growth with mature overstory.
C – Open stand of mature timber.
D – Open stand of mature timber with medium-stocked understory.
E – Hardwood cover.
F – Clear-cut area.
G – Medium-stocked second growth with scattered merchantable timber.
H – Dense, all-size-class stand.



AFTER TREATMENT

A – Dense, second-growth, thinned without reducing shade.
B – Careful removal of overstory leaves adequate shade from second-growth understory.
C – Open stand provides only partial shade; therefore, no cutting. Establish protective understory before removing overstory.
D – Short, steep gradient allows overstory removal, leaving medium-stocked understory to provide shade.
E – Hardwood cover furnishes only shade; therefore, area should be undisturbed.
F – Clear-cut area raises stream temperature. Regenerate as quickly as possible.
G – Maintain existing cover to prevent heated water from heating further.
H – Careful removal of dominant and co-dominants still provides adequate shade from residual stands.

SECTION X

APPENDIX

APPENDIX

PART 1

HYDROMETEORLOGICAL DATA SUMMARY

NEZPERCE NATIONAL FOREST and VICINITY

Ave. Monthly and Annual Precipitation

Mean Montly Air Temperatures

Ave. Snow Depth and Water Equivalents

Annual Water Yields at U.S.G.S. Stations

NEZPERCE NATIONAL FOREST AREA
STATION PRECIPITATION SUMMARIES (Ave. Monthly - Annual.
Data in Inches

STATION	ELEV.'	J	F	M	A	M	J	J	A	S	O	N	D	ANNUAL
Kamiah	1212	1.87	1.65	2.04	2.38	2.47	2.34	.64	.75	1.35	1.97	2.21	2.04	21.71
Kooskia	1261	2.08	1.81	2.30	2.69	3.01	2.51	.88	.77	1.54	2.26	2.40	2.00	24.25
Slate Cr.	1568	1.78	.70	1.58	1.58	1.72	2.23	.33	1.17	1.34	1.75	1.15	1.07	[illegible]
Fenn R.S.	1580	3.66	3.81	3.78	3.23	3.84	3.28	.87	1.06	2.13	3.29	4.47	4.61	[illegible].03
Slims Camp*	1800	4.34	3.39	3.48	3.62	3.32	2.86	.71	1.57	1.95	2.95	3.82	4.25	[illegible].25
Riggins	1801	1.02	1.27	1.47	1.54	2.10	1.80	.58	.59	1.04	1.30	1.29	1.39	18.39
Campbells Fy.*	2500	1.91	2.12	1.85	2.00	2.51	2.59	.78	1.09	1.24	1.75	1.78	2.05	21.70
Running Cr.*	2840	2.92	2.15	2.40	2.17	2.71	2.60	.78	1.42	1.29	2.19	2.65	2.51	[illegible]
Meadow Cr. G.S.*	3000	2.92	2.29	2.71	2.51	2.82	2.82	1.39	1.90	1.79	2.44	2.80	2.59	28.[illegible]
Grangeville	3355	1.66	1.57	2.21	2.63	3.38	3.10	.87	.87	1.72	2.25	1.94	1.62	23.[illegible]
Cottonwood	3411	1.85	1.65	1.77	1.94	2.72	2.65	.97	.99	1.44	1.79	2.02	1.74	21.53
Elk City	4049	3.37	2.50	3.44	2.50	3.00	3.33	1.18	1.49	1.09	2.48	2.95	2.49	29.82

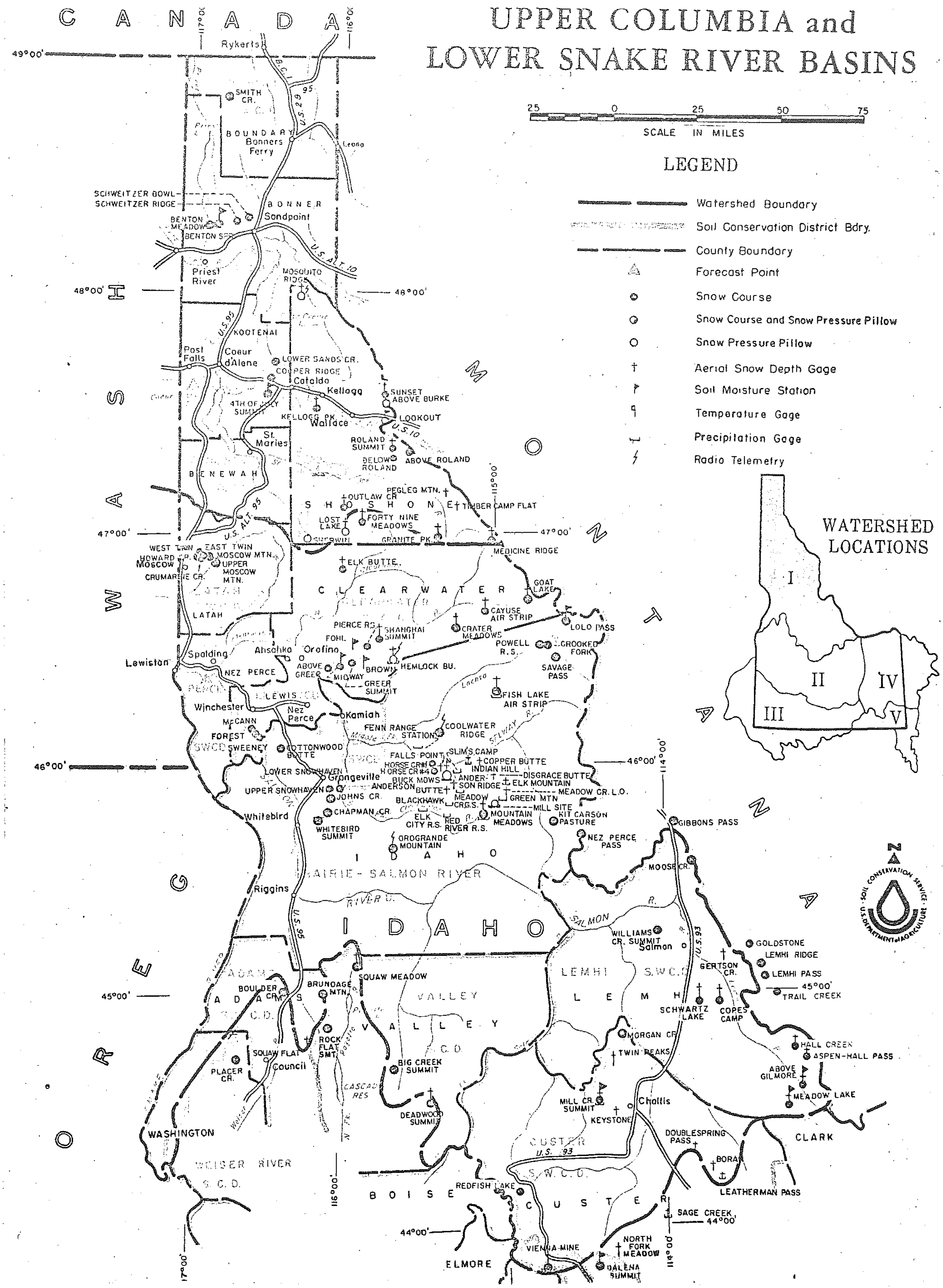
STATION PRECIPITATION SUMMARIES
(CONT.)

Station	ELEV'	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Horse Cr.	4100	4.28	3.44	3.49	3.84	3.45	2.74	.87	1.37	1.84	3.02	3.84	4.29	36.45
Red R. *	4300	2.62	2.01	2.40	2.24	2.50	2.50	1.10	1.53	1.42	2.12	2.38	2.38	25.20
Buck Mdws	5600	4.22	4.19	4.29	4.43	4.18	3.35	1.27	2.31	2.54	3.63	4.70	5.23	44.44
Dixie	5610	5.12	2.71	2.38	2.53	2.20	3.11	.71	1.46	1.74	2.68	2.56	3.22	30.42
Indian [illegible] *	6100	4.18	3.03	3.49	3.23	3.82	3.73	1.30	2.09	2.02	3.14	3.78	3.76	37.56
Blackhawk*	6100	4.59	3.19	4.19	3.96	4.39	4.38	1.88	2.69	2.54	3.70	4.19	4.15	44.07
Mtn. Mdws *	6200	5.26	4.10	4.80	4.50	4.97	5.03	2.35	3.18	3.05	4.27	4.56	4.76	50.83
Burnt Knob*	6400	3.93	2.97	3.43	3.09	3.75	3.56	1.37	2.16	2.02	3.12	3.63	3.58	36.60
Nezperce Pass	6589	3.92	2.88	3.08	3.04	2.93	2.78	.96	1.42	1.74	2.70	3.12	3.74	32.31
Green Mtn.*	7200	4.22	3.46	4.19	3.86	4.13	4.08	1.92	2.51	2.41	3.50	3.95	3.99	42.45
Elk Mtn.*	7500	6.01	4.57	4.90	4.55	4.82	5.20	1.68	2.69	2.46	4.28	5.24	5.34	57.71

* Monthly Data estimated from statistical comparison w/ surrounding stations.

NEZ PERCE NATIONAL FOREST AREA
STATION AIR TEMPERATURE SUMMARIES (Mean Monthly)
Data in °F

STATION	ELEV'	J	F	M	A	M	J	J	A	S	O	N	D	YR.
Kooskia	1261	29.3	35.4	42.7	50.6	57.8	64.3	71.9	69.9	61.6	50.9	38.7	32.3	50.5
Slate Cr	1568	31.9	41.4	43.5	51.6	59.2	66.3	75.2	75.3	66.0	53.4	45.0	31.8	54.4
Fenn	1580	28.7	35.1	40.7	49.1	57.1	62.9	71.0	69.6	61.4	50.6	31.7	32.6	49.7
Riggins	1801	36.0	40.8	45.1	52.4	61.0	67.0	76.2	75.8	66.8	54.6	44.3	36.7	54.7
Grangeville	3355	29.7	33.5	36.9	43.4	51.6	58.3	66.5	64.6	57.7	46.6	31.5	30.6	46.4
Cottonwood	3411	26.4	30.3	35.8	43.3	50.8	57.1	65.9	64.7	56.7	46.9	35.8	28.8	45.2
Elk City	4049	23.3	27.1	29.7	38.7	47.1	54.0	60.6	59.2	52.6	42.0	31.9	24.6	41.0
Mouse Cr.	4100	27.0	26.7	33.0	35.1	42.8	52.8	61.5	59.5	52.6	39.8	29.5	29.3	40.8
Red River	4300	25.2	30.0	42.6	41.0	48.5	53.3	61.0	60.1	49.7	43.5	33.3	24.3	40.7
Buck Mdws.	5600	30.5	27.1	31.8	34.3	41.1	51.1	60.0	60.8	53.0	40.7	32.2	25.5	40.7
Dixie	5610	18.7	22.1	25.2	34.5	43.1	50.3	57.5	56.5	49.3	38.4	29.4	20.9	37.2
Mtn. Mdws	6300	25.8	24.6	27.1	31.6	41.6	46.1	54.3	54.2	47.5	38.1	29.3	22.5	36.9
Mill Site	6600	27.1	24.8	28.6	33.6	45.0	49.6	59.9	58.6	51.7	40.0	30.3	22.1	39.3


UPPER COLUMBIA and
LOWER SNAKE RIVER BASINS
25 0 25 50 75
SCALE IN MILES
LEGEND
Watershed Boundary
Soil Conservation District Bdry.
County Boundary
Forecast Point
Snow Course
Snow Course and Snow Pressure Pillow
Snow Pressure Pillow
Aerial Snow Depth Gage
Soil Moisture Station
Temperature Gage
Precipitation Gage
Radio Telemetry
WATERSHED
LOCATIONS
I
II
III
IV
V
CANADA
WASHINGTON
OREGON
MONTANA
IDAHO
49°00'
48°00'
47°00'
46°00'
45°00'
44°00'
117°00'
116°00'
115°00'
114°00'
Rykerts
SMITH CR.
BOUNDARY
Bonners Ferry
SCHWEITZER BOWL
SCHWEITZER RIDGE
BENTON MEADOW
BENTON SPR.
BONNER
Sandpoint
Priest River
MOSQUITO RIDGE
KOOTENAI
Post Falls
Coeur d'Alene
LOWER SANDS CR.
COOPER RIDGE
Cataldo
Kellogg
SUNSET
ABOVE BURKE
4TH OF JULY SUMMIT
KELLOGG PK.
Wallace
LOOKOUT
St. Maries
ROLAND SUMMIT
BELOW ROLAND
ABOVE ROLAND
BENEWAH
PEGLEG MTN.
OUTLAW CR
SHOSHONE
TIMBER CAMP FLAT
LOST LAKE
FORTY NINE MEADOWS
GRANITE PK.
MEDICINE RIDGE
WEST TWIN
EAST TWIN
HOWARD CR.
MOSCOW MTN.
Moscow
UPPER MOSCOW MTN.
CRUMARINE CR.
LATAH
ELK BUTTE
CLEARWATER
GOAT LAKE
CAYUSE AIR STRIP
PIERCE RS
SHANGHAI SUMMIT
CRATER MEADOWS
LOLO PASS
FOHL
POWELL R.S.
CROOKED FORK
Spalding
Ahsahka
Orofino
Lewiston
ABOVE GREER
MIDWAY
BROWN
HEMLOCK BU.
SAVAGE PASS
NEZ PERCE
GREER SUMMIT
FISH LAKE AIR STRIP
LEWIS
Winchester
Nez Perce
Kamiah
McCANN
FOREST
FENN RANGE STATION
COOLWATER RIDGE
SWEENEY
COTTONWOOD BUTTE
FALLS POINT
SLIMS CAMP
COPPER BUTTE
INDIAN HILL
LOWER SNOWHAVEN
Grangeville
BUCK MDWS
ANDERSON BUTTE
ANDERSON RIDGE
DISGRACE BUTTE
ELK MOUNTAIN
MEADOW CR. L.O.
UPPER SNOWHAVEN
JOHNS CR.
BLACKHAWK
GREEN MTN
MILL SITE
Whitebird
CHAPMAN CR.
ELK CITY R.S.
RED RIVER R.S.
MOUNTAIN MEADOWS
KIT CARSON PASTURE
WHITEBIRD SUMMIT
OROGRANDE MOUNTAIN
GIBBONS PASS
NEZ PERCE PASS
PRAIRIE-SALMON RIVER
MOOSE CR.
Riggins
SALMON R.
WILLIAMS CR. SUMMIT
Salmon
GOLDSTONE
LEMHI RIDGE
GERTSON CR.
LEMHI PASS
TRAIL CREEK
SQUAW MEADOW
BRUNDAGE MTN.
VALLEY
LEMHI
BOULDER CR.
ADAMS
SCHWARTZ LAKE
COPES CAMP
MORGAN CR.
TWIN PEAKS
HALL CREEK
ASPEN-HALL PASS
ABOVE GILMORE
MEADOW LAKE
SQUAW FLAT
ROCK FLAT SMT.
PLACER CR.
Council
BIG CREEK SUMMIT
CASCADE RES
MILL CR. SUMMIT
Challis
KEYSTONE
DEADWOOD SUMMIT
WASHINGTON
WEISER RIVER S.C.D.
CUSTER S.W.C.D.
DOUBLESPRING PASS
BORAH
CLARK
LEATHERMAN PASS
REDFISH LAKE
BOISE
CUSTER
SAGE CREEK
ELMORE
VIENNA MINE
NORTH FORK MEADOW
GALENA SUMMIT
SOIL CONSERVATION SERVICE
U.S. DEPARTMENT of AGRICULTURE

INDEX to SNOW COURSES

UPPER COLUMBIA BASIN

KOOTENAI RIVER

NO.	STATE	NAME	SEC.	TWP.	RGE.	ELEV.
16A1	I	Smith Creek	29	64N	3W	4800

PEND OREILLE - PRIEST RIVER

NO.	STATE	NAME	SEC.	TWP.	RGE.	ELEV.
16A2	I	Benton Meadow	27	58N	4W	2344
16A3M	I	Benton Spring	30	58N	3W	4900
16A6	I	Schweitzer Bowl	20	58N	2W	4500
16A5	I	Schweitzer Ridge	19	58N	2W	6100

SPOKANE RIVER

NO.	STATE	NAME	SEC.	TWP.	RGE.	ELEV.
15B8S	I	Above Burke	11	48N	5E	4100
15B7	I	Above Roland	35	47N	6E	4350
15B6	I	Below Roland	34	47N	6E	3770
16B2	I	Copper Ridge	6 & 7	50N	1W	4800
16B3M	I	Fourth of July Summit	6	49N	1W	3100
15B13A	I	Granite Peak	3	42N	8E	6000
16B5A	I	Kellogg Peak	19	48N	3E	5560
15B2MS	I	Lookout	4	47N	6E	5250
16B1	I	Lower Sands Creek	32	51N	1W	3400
15B4A	I	Medicine Ridge	24	43N	10E	6150
16A4AS	I	Mosquito Ridge	5	54N	2E	5110
15B12A	I	Outlaw Creek	19	44N	5E	3750
15B15a	I	Pegleg Mountain	15	44N	9E	5735
15B5A	I	Roland Summit	26	47N	6E	5200
16C1S	I	Sherwin	28 & 33	42N	1E	3200
15B9A	I	Sunset	28	49N	5E	5600
15B16a	I	Timber Camp Flat	23	44N	9E	4300

LOWER SNAKE BASIN

PALOUSE RIVER

NO.	STATE	NAME	SEC.	TWP.	RGE.	ELEV.
16C6	I	Crumarine Creek	24	40N	5W	3340
16C3	I	East Twin	13	40N	5W	4050
16C5	I	Howard Creek	14	40N	5W	3450
16C2	I	Moscow Mountain	18	40N	4W	4400
16C7SR	I	Upper Moscow Mountain	16	40N	4W	4600
16C4P	I	West Twin	14	40N	5W	4250

LEGEND

Numbering System (example)

10J7	SNOW COURSE ONLY.
10J7P	SNOW COURSE AND PRECIPITATION GAGE.
10J7M	SNOW COURSE AND SOIL MOISTURE STATION.
10J7A	SNOW COURSE AND AERIAL MARKER.
10J7s	PRESSURE PILLOW ONLY.
10J7S	SNOW COURSE AND PRESSURE PILLOW.
10J7MA	SNOW COURSE, SOIL MOISTURE STATION AND AERIAL MARKER.
10J7MP	SNOW COURSE, SOIL MOISTURE STATION AND PRECIPITATION GAGE.
10J7m	SOIL MOISTURE STATION ONLY.
10J7a	AERIAL MARKER ONLY.
10J7p	STORAGE PRECIPITATION GAGE ONLY.

CLEARWATER RIVER

NO.	STATE	NAME	SEC.	TWP.	RGE.	ELEV.
16C11	I	Above Greer	14	35N	2E	1240
15D7a	I	Anderson Butte	34	30N	9E	6800
15D8a	I	Anderson Ridge	35	30N	9E	5400
15D9p	I	Blackhawk	31	29N	10E	6080
16C14m	I	Brown	11	35N	3E	3100
15D5MAP	I	Buck Meadows	26	31N	8E	5600
15C3A	I	Cayuse Airstrip	4	38N	11E	3700
15C7R	I	Coolwater Mountain	32	33N	8E	6200
15D10a	I	Copper Butte	35	31N	10E	6000
16C16	I	Cottonwood Butte	33	32N	1W	5140
15C9A	I	Crater Meadows	2	3[illegible]	9E	6100
14C10	I	Crooked Fork	27	37N	14E	3800
15D11a	I	Disgrace Butte	26	30N	10E	6600
16C15A	I	Elk Butte	6	40N	3E	5550
15D12p	I	Elk City Rgr. Sta.	23	29N	8E	4000
15D13ap	I	Elk Mountain	34	30N	11E	6900
15C11a	I	Falls Point	10	31N	9E	4600
15C12p	I	Fenn Ranger Station	23	32N	7E	1580
15C2AP	I	Fish Lake Airstrip	35	35N	11E	5000
15C8m	I	Fohl	16	36N	5E	3450
16C9	I	Forest	1	32N	3W	4550
15B3A	I	Forty-nine Meadows	6	43N	5E	5000
14C9A	I	Goat Lake	4	38N	13E	6600
15D14p	I	Green Mountain	15	28N	11E	7000
16C13	I	Greer Summit	13	35N	2E	3000
15C6APR	I	Hemlock Butte	7	36N	7E	5500
15C8s	M	Hoodoo Basin	17	14N	27W	6000
15C1	M	Hoodoo Creek	16	14N	27W	5900
15C14	I	Horse Creek #1	25	31N	8E	5500
15C15	I	Horse Creek #4	5	30N	9E	5400
15D21a	I	Horse Point	4	30N	9E	5700
15D22ap	I	Indian Hill	30	31N	10E	6100
14D3	I	Kit Carson Pasture	4	27N	16E	5020
14C5M	I	Lolo Pass	16	38N	15E	5230
15B14AS	I	Lost Lake	16	43N	4E	6000
15D15p	I	Lower Horse Creek	28	31N	9E	4100
16D7	I	Lower Snowhaven	9	29N	3E	5250
16C8	I	McCann	25	33N	3W	43[illegible]
15D16p	I	Meadow Creek Guard Station	5	29N	10E	2[illegible]
15D17a	I	Meadow Creek Lookout	25	29N	11E	7[illegible]
16C12M	I	Midway	14	35N	2E	2200
15D18ps	I	Mill Site	22	28N	11E	6700
15D6AP	I	Mountain Meadows	9	27N	10E	6300
14D1	M	Nez Perce Pass	25	1S	24W	6575
15D4R	I	Orogrande Mountain	24	27N	6E	7800
15C5	I	Pierce Ranger Station	2	36N	5E	3170
14C6	I	Powell Ranger Station	33	37N	14E	4230
15D19p	I	Red River Ranger Station	4	27N	9E	4340
15D20a	I	Sable Hill	14	29N	10E	6000
14C4	I	Savage Pass	18	36N	15E	6600
15C4A	I	Shanghai Summit	7	37N	6E	4600
15C13p	I	Slim's Camp	11	31N	9E	1850
16C10	I	Sweeney	1	32N	3W	4435
16D4	I	Upper Snowhaven	8 & 9	29N	3E	5600

SALMON RIVER

NO.	STATE	NAME	SEC.	TWP.	RGE.	ELEV.
13E19MA	I	Above Gilmore	13	13N	26E	8200
13E21A	I	Aspen-Hall Pass	6	16N	28E	8110
15E2	I	Big Creek Summit	24	15N	5E	6600
13E8a	I	Borah	21	10N	23E	8250
16D6	I	Brundage Mountain	6	19N	3E	7560
16D2	I	Chapman Creek	16	29N	2E	4215
13E17A	I	Copes Camp	36	18N	22E	7500
13E25a	I	Doublespring Pass	3	10N	22E	8400
13D17a	I	Gertson Creek	22	22N	23E	8050
13D2	M	Gibbons Pass	4	2S	19W	7100
13D9	M	Gold Stone	11	8S	16W	8100
13E20A	I	Hall Creek	1	16N	27E	7560
16D3	I	Johns Creek	9	29N	2E	3805
14E6a	I	Keystone	15	13N	18E	7700
13E24ap	I	Leatherman Pass	20	9N	23E	9800
13E1	M	Lemhi Pass	9	10S	15W	7480
13E23	M	Lemhi Ridge	4	10S	15W	8100
13E18MA	I	Meadow Lake	24	13N	26E	9100
14E1MAP	I	Mill Creek Summit	8	13N	17E	8870
13D16	I	Moose Creek	22 & 26	27N	21E	6200
14E4	I	Morgan Creek	32	18N	19E	7580
14E2	I	Redfish Lake	3	9N	13E	6600
13E16A	I	Schwartz Lake	34	18N	22E	8[illegible]
13E2	M	Trail Creek	15	10S	15W	[illegible]
14E3a	I	Twin Peaks	28	15N	17E	10[illegible]
14F4AP	I	Vienna Mine	32	6N	14E	8900
16D5	I	[illegible] Summit	17	29N	[illegible]	[illegible]
14D4	I	Williams Creek Summit	36	[illegible]	[illegible]	[illegible]

NEZPERCE NATIONAL FOREST AREA
AVE. SNOW DEPTH & WATER EQUIVALENT
Data in Inches

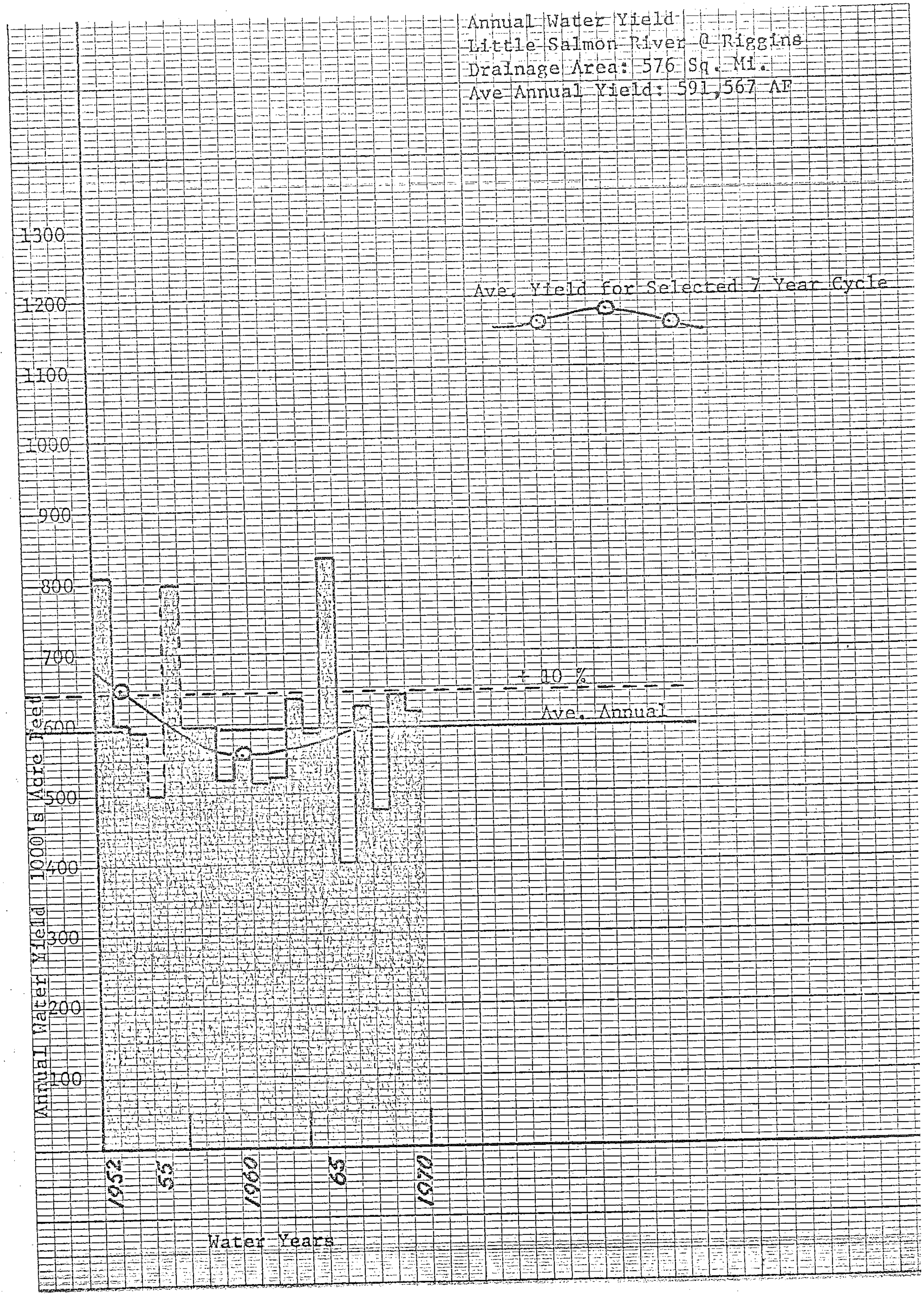
STATION	ELEV '	JAN 1		FEB 1		MAR 1		APR 1		MAY 1	
		S.D.	W.E.	S.D.	W.E.	S.D.	W.E.	S.D.	W.E.	S.D.	W.E.
Johns Cr.	3805	5	1.0	7	1.9	5	1.5	2	.6	0	0
Chapman Cr.	4215	8	1.6	12	3.1	9	2.7	6	2.2	1	.2
Powell R.S.	4230	26	5.3	43	12.6	38	12.7	33	12.8	1	.7
Whitebird Sum.	4390	12	2.4	19	5.1	18	5.6	16	5.8	1	.4
Forest	4550			23	6.5	21	6.7	16	6.1		
Falls Pt.	4600	46	12.3	41	11.9	43	15.6	45	18.2	28	12.2
Fish Lake A.S.	5000	60	16.4	91	28.7	104	37.9	110	42.1	96	43.3
Kit Carson Past.	5020	17	3.7	21	5.1	25	6.2	23	8.3	2	.6
Lolo Pass	5230	56	13.0	77	22.1	81	28.2	83	33.1	64	33.1
Horse Cr #4	5400	59	15.2	69	19.3	63	20.9	67	26.9	88	30.4
Anderson Ridge	5400	33	8.9	50	14.3	52	17.9	44	17.0	44	19.4
Horse Cr. #1	5500	59	14.0	69	20.9	56	20.7	56	22.5	34	13.6
Buck Mdws.	5600	50	12.9	61	19.1	69	23.7	77	32.1	72	33.3
Horse Pt.	5400	48	11.8	50	14.5	49	19.0	59	24.1	57	21.3

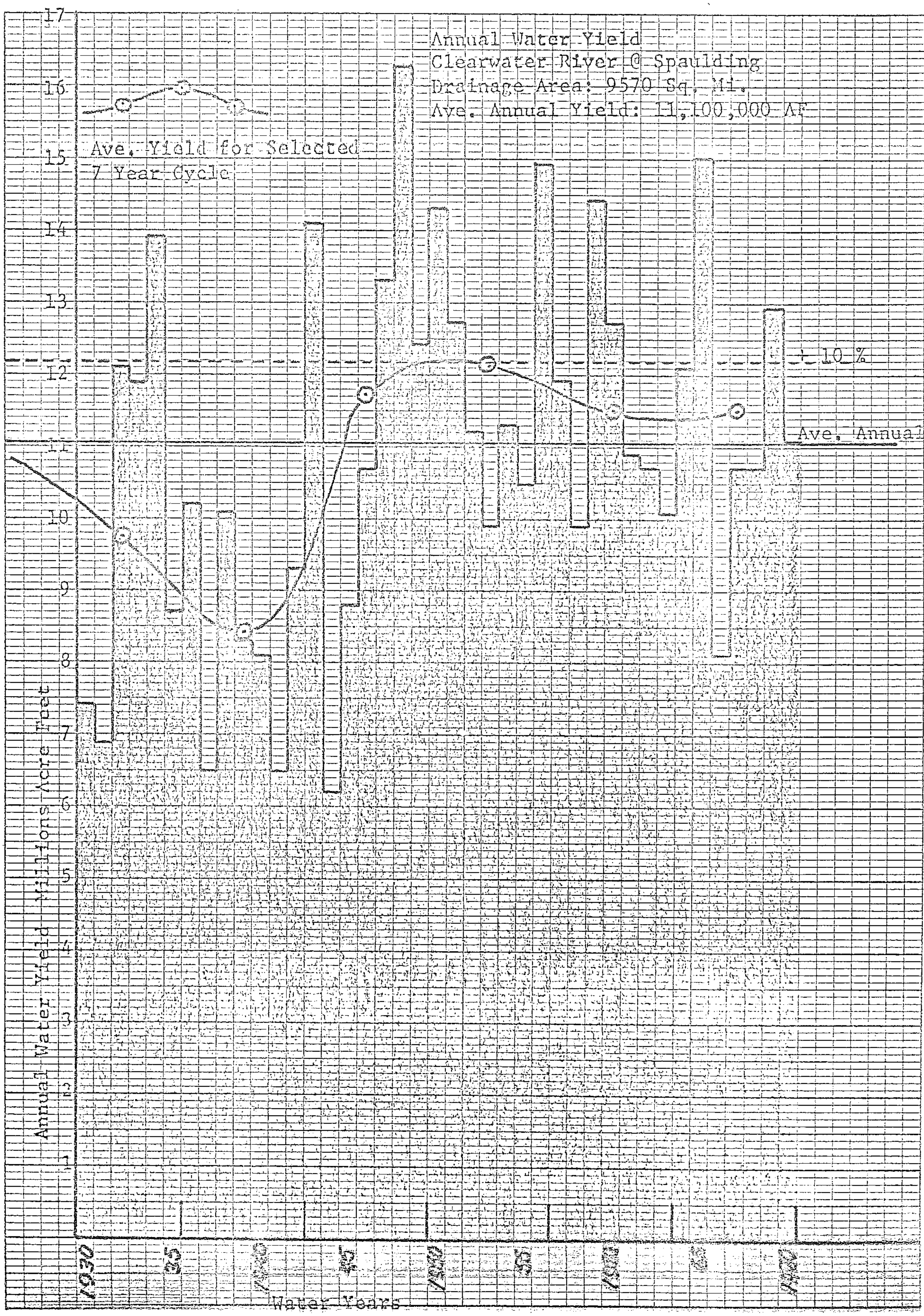
AVE. SNOW DEPTH & WATER EQUIVALENT
(CONT.)

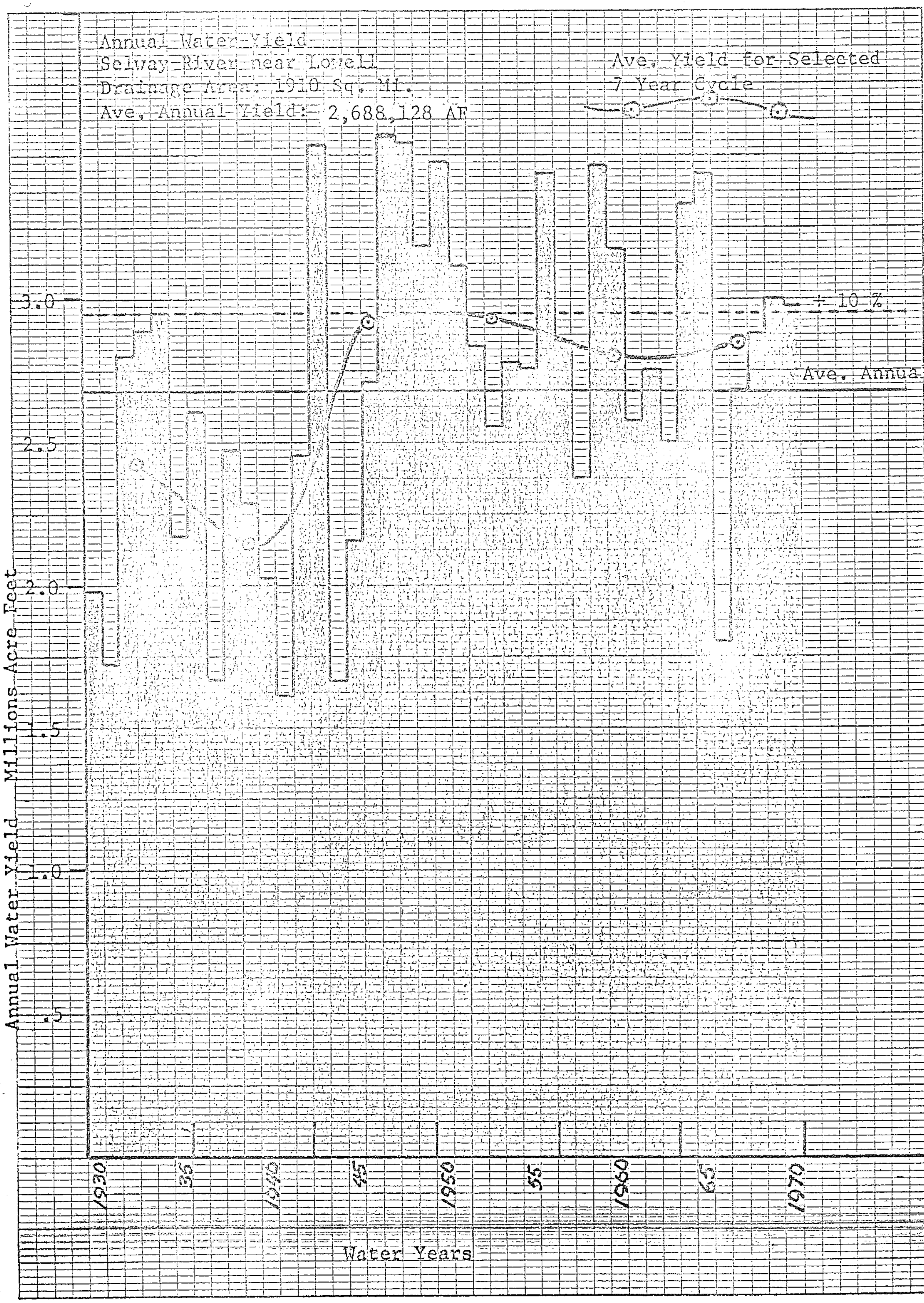
STATION	ELEV'	JAN 1 SD	JAN 1 WE	FEB 1 SD	FEB 1 WE	MAR 1 SD	MAR 1 WE	APR 1 SD	APR 1 WE	MAY 1 SD	MAY 1 WE
Copper Butte	6000	50	13.9	67	17.8	72	25.3	90	33.9	98	37.4
Sable Hill	6000	37	9.3	45	12.7	49	17.6	56	22.4	52	22.4
Indian Hill	6100	27	7.9	41	11.4	37	14.3	43	17.1	36	16.5
Coolwater Mtn.	6200		10.9		18.7	100	31.3	84	33.7	79	34.3
Mtn. Meadows	6300	47	11.3	56	18.0	63	20.1	67	26.9	66	29.0
Nezperce Pass	6575	40	10.9	48	14.7	50	17.6	33	13.1	16	6.8
Disgrace Butte	6600	54	13.2	59	18.0	68	23.5	76	28.8	79	31.9
Savage Pass	6600	43	10.5	71	20.7	70	23.7	75	27.4	56	25.0
Mill Site	6700	50	14.0	76	22.7	76	25.9	90	31.9	100	38.7
Anderson Butte	6800	67	16.1	77	20.0	90	30.4	102	38.4	110	44.0
Meadow Cr. L.O.	7000	69	16.8	74	22.6	81	27.8	95	36.1	94	37.7
Elk Mtn.	7500	88	20.6	103	32.2	105	36.2	122	47.0	121	49.4
Orogrande Mtn.	7800		21.1		36.0	99	37.3	108	42.0	117	49.1

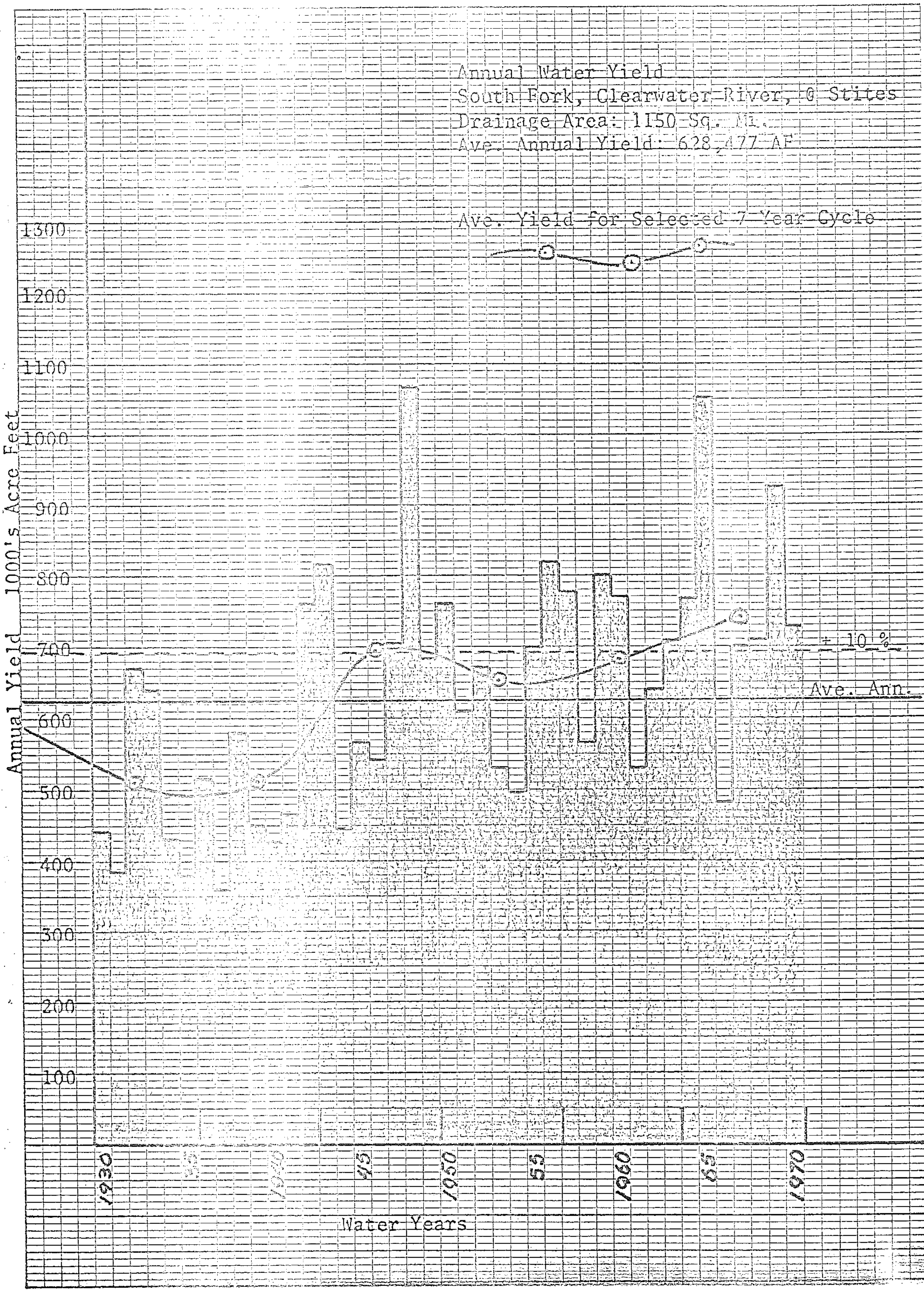
Note: S.D. = Snow Depth, Inches
W.E. = Water Equivalent, Inches


Ave. Yield for Selected
7 Year Cycle
Annual Water Yield
S. Fork, Clearwater R. near Elk City.
Drainage Area: 261 Sq. Mi.
Ave. Annual Yield: 190,750 AF
+ 10 %
Ave. Ann. Yield
300
250
200
150
100
50
40
30
20
10
Annual Water Yield 1000's Acre Feet
1945
1950
55
1960
65
1970
Water Years


Annual Water Yield
Little Salmon River @ Riggins
Drainage Area: 576 Sq. Mi.
Ave Annual Yield: 591,567 AF
Ave. Yield for Selected 7 Year Cycle
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
Annual Water Yield 1000's Acre Feed
± 10 %
Ave. Annual
1952
55
1960
65
1970
Water Years


Annual Water Yield
Clearwater River @ Spaulding
Drainage Area: 9570 Sq. Mi.
Ave. Annual Yield: 11,100,000 AF
Ave. Yield for Selected
7 Year Cycle
+ 10 %
Ave. Annual
Annual Water Yield Millions Acre Feet
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1930
35
45
1950
55
1960
1970
Water Years


Annual Water Yield
Selway River near Lowell
Drainage Area: 1910 Sq. Mi.
Ave. Annual Yield: 2,688,128 AF
Ave. Yield for Selected
7 Year Cycle
+ 10 %
Ave. Annual
3.0
2.5
2.0
1.5
1.0
.5
Annual Water Yield Millions Acre Feet
1930
35
1940
45
1950
55
1960
65
1970
Water Years



Annual Water Yield
South Fork, Clearwater River, @ Stites
Drainage Area: 1150 Sq. Mi.
Ave. Annual Yield: 628,477 AF
Ave. Yield for Selected 7 Year Cycle
Annual Yield 1000's Acre Feet
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
+ 10 %
Ave. Ann.
1930
35
1940
45
1950
55
1960
65
1970
Water Years

APPENDIX

PART 2

U.S. WATER NEEDS, ESTIMATED WATER REQUIREMENTS,

VALUE FO AN ACRE FOOT OF WATER, AVERAGE ANNUAL YIELD

FROM R-1 NATIONAL FORESTS

The Water Picture Year 2020

WATER NEEDS IN THE U.S. WILL INCREASE FIVE-FOLD OVER THE NEXT 50 YEARS. That's the conclusion of the Federal Water Resources Council which has just completed its first national water assessment.

The Water Resources Council in its November 1968 "First National Assessment of the Nation's Water Resources" report to President Johnson has estimated water use and projected requirements for the United States as follows:

Total withdrawals of water, amounting to 270 billion gallons per day in 1965, will rise to 1,370 billion gallons per day in 2020, says the report. Consumptive uses--which do not result in water being returned directly to watercourses--will double from 78 billion gallons a day to 157 billion gallons per day. (See table on following page.)

The largest projected increases will be for domestic and municipal use (300 percent), industrial use (400 percent), and cooling for steam-electric powerplants (over 600 percent). The large withdrawals expected indicate that even with expanded water recycling by industry, a large increase in water reuse will be required. This means that we must expect much larger investments in the future for water development, water conditioning, waste treatment, and water management. (See following table.)

Assumptions which guided the estimate were:

--That the population will grow about 1.6 percent a year, leading to a population in 2020 of 468 million, contrasted to the 1965 population of 195 million.

--That land used for crops and pasture will be about the same in 2020 as today, but will produce enough food and fiber for two and one-half times as many people.

--That growth patterns will result in most new industries locating in or close to existing metropolitan areas, resulting in a few huge strip cities including the major portion of the nation's population and economic activity.

In view of the magnitude of the task of meeting oncoming water demands, the Council has prepared an array of far-reaching recommendations. Among these are actions to reserve favorable reservoir sites, expand flood plain management, achieve desirable water quality, improve recreational opportunities, protect shores and banks, and identify alternative means of meeting needs of water-short regions. The Council also calls for "increased emphasis on land treatment and management of agricultural and other water-related lands to protect streams and water supplies from siltation" and says that more attention should be given to planning for land undergoing urban development.

It's no surprise to Conservation District officials that water needs are expanding drastically. What will be needed in the years ahead is the determination to meet these needs as efficiently as possible in a manner that preserves associated resources and provides maximum benefits to all the people. Land and water conservation measures, sediment control, and upstream watershed development will continue to grow in significance as the nation grapples with the water problems of the future.

(Million Gallons Daily)

Type of Use	Withdrawals: Used '65	Withdrawals: Projected Requirements 1980	Withdrawals: Projected Requirements 2000	Withdrawals: Projected Requirements 2020	Consumptive Use: Used '65	Consumptive Use: Projected Requirements 1980	Consumptive Use: Projected Requirements 2000	Consumptive Use: Projected Requirements 2020
Rural, domestic	2,351	2,474	2,852	3,334	1,636	1,792	2,102	2,481
Municipal (Public Supplied)	23,745	33,596	50,724	74,256	5,244	10,581	16,478	24,643
Industrial (Self Supplied)	46,405	75,026	127,365	210,767	3,764	6,126	10,011	15,619
Steam-Electric Power:								
Fresh Water	62,738	133,963	259,208	410,553	659	1,685	4,552	8,002
Saline Water	21,800	59,340	211,240	503,540	157	498	2,022	5,183
Agriculture:								
Irrigation	110,852	135,852	149,824	160,978	64,696	81,559	89,964	96,919
Livestock	1,726	2,375	3,397	4,660	1,626	2,177	3,077	4,238
Totals	269,617	442,626	804,610	1,368,088	77,782	104,418	128,206	157,085

"The nation's renewable water resources are derived from an average annual precipitation of 30 inches, equivalent to 4,200 billion gallons per day on the conterminous United States. About 70% of this precipitation is consumed through evaporation and transpiration. A portion of this evapotranspiration provides 80% of our supply of food and fiber and nearly 100% of our forest products. The remaining 30% of this precipitation constitutes the nation's average annual runoff of about 9 inches, or 1,200 billion gallons per day. A substantial part of this is physically subject to development under present technology. In addition, large amounts of [illegible] ene[illegible]e g[illegible]d w[illegible]r st[illegible]ge [illegible] be [illegible]lop[illegible]"

ESTIMATED WATER REQUIREMENTS

Source of data: American Water Works Assn., Chemical Engineer, Ohio Water Resource Board, National Assn. of Manufacturers, Council of National Water Policy, Federal Reserve Bank of Dallas, Standard Oil of N. J., Engineers' Joint Council, Oregon State College, U. S. Geological Survey, Forest Products Laboratory, U. S. Department of Agriculture, Encyclopedia Britannica.

Product or Facility	Unit or Service	Gallons Water Required
Alcohol	Gallon	100
Aluminum	Ton	32M
Animal	Cow, Horse, Mule	10-12
	Sheep, Swine, Chicken	1
Beef Steak	Lb. (to grow)	1.3M
Beer	Barrel	470
Cheese	Ton	400
City (all uses)	Per person per day	150
Corn	Bushel (to grow)	5M
Dairy products (general)	Ton	680
Gasoline	Gallon	0
Gasoline (synthetic)	Barrel	1,500
Irrigation (of farm crops)	One acre	2 acre feet
Laundry	Lb. of clothes	4½-5½
Lawn Grass	Acre	6 acre feet
Office	Per person per day	27-45
Oil (petroleum refining)	Barrel	770
Recreation Use:		
Campground	Per person per day	30
Hotels and resorts	" " " "	125
Organization camps	" " " "	40
Picnic areas	" " " "	20
Summer homes	" " " "	100
Wilderness areas	" " " "	5
Winter sports areas	" " " "	15
Restaurant	1 meal	1/2-4
Soft drinks	Case	2½
Steel (highly finished)	Ton	65M
(rolled)	Ton	27.9M
Wheat (to grow)	1 Bushel	4M
Whiskey	Gallon	80

Paper and Pulp	Unit	Water Required	Actual Consumption
Sulfite pulp, unbleached	Ton	50M	
Sulfite pulp, bleached	Ton	95M	4
Kraft pulp, unbleached	Ton	35M	
Sulfate pulp, bleached	Ton	92M	4
Ground wood pulp	Ton	10M	314
Hardboard, wet batch	Ton	2.5M	235
Hardboard, wet, continuous	Ton	10M	235
Insulation board	Ton	8M	235
Lumber (Sawmill)	Bd. Ft.	1 gal.	
Pasteboard	Ton	14M	

Caution - These figures are interesting, but they may be misleading. Far too often they reflect the fact that water is easily available, inexpensive, and therefore often used inefficiently.

Value of an Acre Foot of Water*

Use	Mean Dollar Value	Maximum Dollar Value
Domestic	100.19	235.66
Industrial	40.73	163.35
Irrigation	1.67	27.04
Power	.71	5.90
Waste Disposal	.63	2.56
Inland Navigation	.05	1.17
Commercial Fisheries	.025	1.06

*Reported by E. F. Renshaw, Journal of American Water Works Association, March 1958.

The cost of water to most municipal, industrial and irrigation users does not reflect the true value but rather a service charge for delivery.

$ 22,000	acre feet of petroleum)	
$ 100,000	acre feet of milk)	September 1963 Scientific American
$1,000,000	acre feet of whiskey)	

AVERAGE ANNUAL WATER YIELD FROM NATIONAL FOREST SYSTEM LANDS

Forest	Acres	Runoff Total Ac.Ft.	Runoff A.F./Ac	Runoff In./Ac.
Beaverhead	2,111,070	1,683,000	.796	9.56
Bitterroot-Ida.	460,812	1,010,000	2.19	26.28
Bitterroot-Mont.	1,115,107	1,440,000	1.29	15.48
Clearwater	1,676,639	5,000,000	2.98	35.76
Coeur d'Alene-Ida.	723,388	1,795,000	2.48	29.76
Colville	933,045	980,000	1.05	12.60
Custer-Beartooth Montana	577,450	845,000	1.46	17.52
Custer-Ashland, Etc., Mont.	534,724	227,000	0.42	5.04
Deerlodge-East	544,562	195,000	0.358	4.30
Deerlodge-West	637,024	820,000	1.29	15.48
Flathead	2,341,477	4,540,000	1.94	23.28
Gallatin	1,701,338	1,780,000	1.046	12.55
Helena-East	552,330	195,000	0.35	4.20
Helena-West	416,670	120,000	0.29	3.48
Kaniksu-Wash.	282,743	541,000	1.91	22.92
Kaniksu-Idaho	891,629	1,770,000	1.98	23.56
Kaniksu-Mont.	447,216	420,000	0.92	11.04
Kootenai	1,819,376	2,045,000	1.12	13.44
Lewis & Clark	1,834,196	1,435,000	0.78	9.36
Lolo	2,086,011	3,130,000	1.50	18.00
Nezperce	2,196,808	2,970,000	1.35	16.20
St. Joe	862,589	1,090,000	1.26	15.12

Based on USGS Water Supply Papers

The public lands in the 11 western states yield an average annual natural runoff of approximately 223 million acre-feet. This compares to the total average annual natural runoff from the entire area of those states of about 363 million acre-feet. Forest Service lands contribute 88 per cent of the public land water and the National Park Service lands contribute almost nine per cent of the public land water.

APPENDIX

PART 3

COLUMBIA-NORTH PACIFIC REGION

WATER RESOURCES

CHAPTER 16

The Nation's Water and Related Land Resources

Columbia-North Pacific Region

SUMMARY

The Columbia-North Pacific Region occupies a diversified area of 274,400 square miles, commonly known as the Pacific Northwest. Elevations range from sea level to over 14,000 feet, and rainfall varies from less than 8 inches to over 200. Summers, however, are consistently dry.

The Region's economy is based on its land, mineral, and water resources. Agriculture is a major activity, but, of the commodity-producing industries, manufacturing provides the largest source of income. Fish and wildlife resources and the abundant recreation opportunities are also important. The population—5.4 million in 1960—is expected to reach 7.6 million by 1980 and 14.4 million by 2020. Employment is expected to increase by 180% from 1960 to 2020. Land use projections reflect a small but continuing transfer of land from agricultural to non-agricultural uses.

Although the water supply in total is abundant, areal distribution varies widely and seasonal flows are low in many of the smaller streams. The available average annual natural runoff is 258 bgd (289 maf/yr), of which 19% (48 bgd) originates in Canada. With few exceptions, the quality of the water is good.

Total present withdrawals average 29.7 bgd (33.3 maf/yr), of which 10.5 bgd (11.8 maf/yr) are consumed. About 95% of the consumption is accounted for by irrigation. The main instream uses are hydroelectric power generation, fish and wildlife habitat, recreation, navigation, and assimilation of wastes. The present water supply is generally adequate, but localized seasonal shortages for virtually all uses occur because development of water and related land resources (including proper control measures) has not kept pace with demands for the resources.

Total consumptive use is projected to increase to 16.0 bgd (17.9 maf/yr) by 1980 and 31.3 bgd (35.0 maf/yr) by 2020. Withdrawals for these uses will increase, respectively, to 47.4 and 178.9 bgd (53.1 and 201 maf/yr). One of the largest uses will continue to be irrigation, which is projected to increase from 6.6 to 17 million acres by 2020. Another large user will be steam-electric powerplants. In the near future, over 1 million additional kilowatts of installed steam-electric capacity will be required each year, and by 2020 withdrawals for cooling water are expected to be 97.2 bgd (109 maf/yr). Municipal and industrial demands will also increase substantially. Instream demands for fish and wildlife, recreation, navigation, and quality control are expected to increase with increases in population and industrialization. All lands are expected to be utilized more intensively to meet the increasing needs of the people. This will necessitate improved management, development, and control of the Region's water and land resources from the upper watersheds covered with timber and grass to the major river valleys.

Although regional water supplies are generally adequate to meet projected consumptive uses for the year 2020, serious depletions will occur in some of the interior basins of eastern Washington and Oregon and southern Idaho. Such depletions will have adverse effects on water quality and instream uses.

In general, the growth of the Region is dependent on its water and land resources. As population and industry grow, needs and demands for additional development and better management of these resources will increase. To meet these needs, the level of Federal and State investment in water and related land resources development and management must increase substantially over the present level—some $250 million annually. Information is not available for other public and the many private interests, but their future investments will also greatly increase.

DESCRIPTION OF THE REGION

Within its 274,400 square miles, the Columbia-North Pacific Region encompasses all of Washington, most of Oregon and Idaho, and parts of Montana, Nevada, Wyoming, and Utah. It includes the drainage area of the Columbia River basin within the United States, the portion of the Great Basin within Oregon, and the coastal areas of Oregon and Washington. (See fig. 6–16–1, which also shows the 12 subregions adopted for study purposes.)

Physiographically, the Region is diverse. The Coast Range of hills and low mountains parallels the ocean a few miles back from the shore. East of the Coast Range is the Willamette-Puget Trough, a broad structural valley extending from Cottage Grove, Oregon, into Puget Sound, Washington. Farther east rise the Cascades, a range of more formidable mountains with several peaks above 10,000 feet. East of the Cascades lie the basin and range area, the Columbia Basin, the lava plateaus, the Snake Plain, and the numerous ranges and intermontane valleys of the Rocky Mountain system. The regional drainage pattern is dominated by the Columbia River and its principal tributaries, the Kootenai, Pend Oreille, Spokane, Yakima, Snake, and Willamette Rivers.

The climate reflects the physiographic diversity. West of the Cascades it is characteristically maritime; winters are mild, summers cool, and humidity and rainfall are relatively high, except during the summer when prolonged droughts are usual. East of the Cascades, temperature extremes are greater and rainfall is generally less. Precipitation varies greatly with exposure and elevation. Some areas in the central plains are extremely arid with average annual precipitation as little as 8 inches. Throughout the Region, precipitation is greatest in the winter and scant during the summer months except along

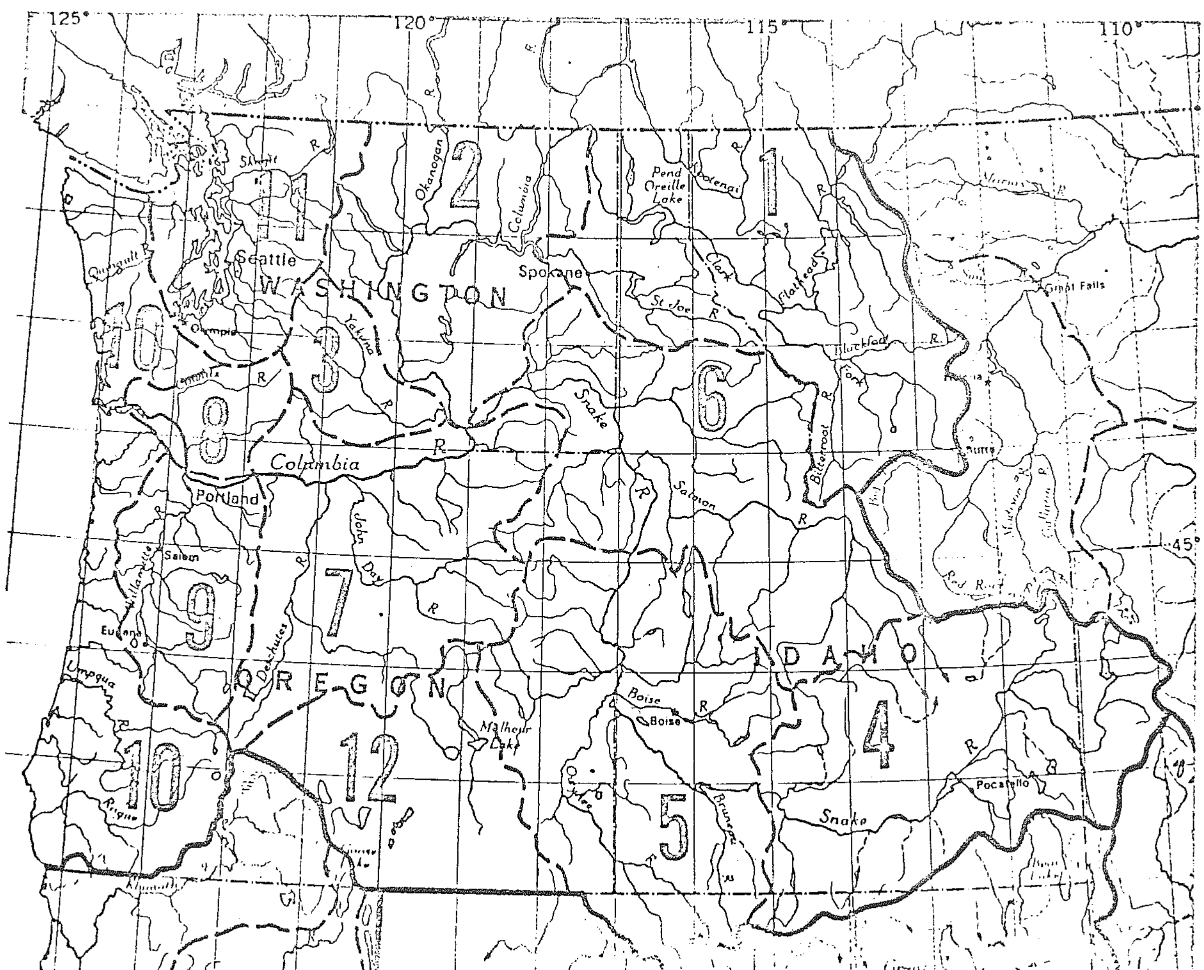


FIGURE 6–16–1.—*Map of the Columbia-North Pacific Region.*

the Continental Divide where it is about uniform.

Population in 1960 was 5,359,000. Almost 60% of the people live in the Willamette-Puget Trough. Rural population densities are related to the intensity of agriculture; thus, desert, forest, and mountain areas are generally sparsely peopled.

The Region's economy is based chiefly on its land, mineral, and water resources. Agriculture is a major economic activity, and its productivity is due in great part to successful irrigation. Tourism has grown rapidly with utilization and development of the abundant fish and wildlife resources and recreation opportunities.

Manufacturing, however, is the largest source of income. Lumber and wood products and the related pulp and paper industry account for about one-third of total manufacturing employment, but transportation-equipment manufacturing, food processing, and production of metals and chemicals are also important. Factors influencing this industrial growth and economic development include the large quantities of low-cost hydroelectric power, the abundance of water for industrial use, and the excellent deep-draft port facilities.

THE WATER RESOURCE

The average annual natural runoff of the Region is 210 bgd (236 maf/yr). Its distribution, together with the 48 bgd (54 maf/yr) originating in Canada, is shown in table 6–16–1. As can be seen in the table, runoff varies greatly among the subregions. Estimates of natural runoff available 50%, 90%, and 95% of the time for each subregion and for the Region as a whole are also given to indicate annual dependability.

Reservoirs and natural lakes of more than 40 acres and streams more than one-eighth of a mile wide provide almost 2 million acres of water surface.

Streams west of the Cascade Range are characterized by high flows in winter and low flows in summer. The main Columbia River and its tributaries east of the Cascades are generally high in spring and early summer and low in fall and winter.

TABLE 6–16–1.—*Annual natural runoff, Columbia-North P 'cific Region*

Subregion	Drainage area	Average runoff		Annual flow exceeded in indicated percent of years			Total average runoff available to subregion [1]
				50	90	95	
	sq. mi.	*bgd*	*in/yr*	*bgd*	*bgd*	*bgd*	*bgd*
1	36,400	26.40	15.23	26.40	16.58	13.81	33.22
2	22,400	6.73	6.31	6.73	4.49	3.85	80.63
3	6,100	2.90	9.98	2.90	2.01	1.75	2.90
4	35,900	8.69	5.08	8.60	4.69	3.73	8.69
5	36,800	7.09	4.05	6.96	3.50	2.70	15.78
6	35,100	20.58	12.31	20.58	13.73	11.77	36.36
7	29,600	9.91	7.03	9.91	7.03	6.11	129.72
8	5,100	13.29	54.72	13.29	9.37	8.27	167.65
9	12,000	24.64	43.12	24.64	17.37	15.33	24.64
10	23,800	53.90	47.56	53.90	38.00	33.53	53.90
11	13,300	35.00	55.26	35.00	26.46	24.04	35.58
12	17,900	0.88	1.03	0.81	0.29	0.20	0.88
Regional value	274,400	210	16.07	210	154	138	258
Annual Canadian contribution to Columbia-North Pacific Region							
1	8,100	6.82	17.67	6.82	4.28	3.57	
2	31,400	40.60	27.17	40.60	27.69	21.23	
11	400	0.58	28.88	0.58	0.40	0.30	
Canadian value	39,900	48.0	25.26	48.0	32.7	25.1	

[1] Total average runoff available to subregion includes Canadian water and all other water that originates upstream from but flows through the subregion in question. The sum of subregions 8, 10, 11, and 12 equals 258 bgd, the total water available to the Region.

Major groundwater aquifers capable of yielding moderate to large supplies of water for irrigation, municipal, and industrial use underlie about one-fourth of the Region. In most of the remainder, small to moderate supplies can be obtained from groundwater. The quality is generally good, although hard water is common east of the Cascade Range.

In contrast to conditions in many parts of the Nation, quality of this Region's surface water is generally very good. Significant quality problems do exist in some areas, however. Dissolved solids concentrations average less than 300 ppm in major water supply sources, although there are exceptions in some isolated areas. Some areas of eastern Washington and Oregon and southern Idaho contribute large amounts of sediment to watercourses. Nitrate and phosphate concentrations from both natural and man-made sources are resulting in excessive algal growths in the Yakima and Snake River basins and in areas of the Columbia Basin Project. During the summer months, water temperatures in many streams rise to levels undesirable for fish life. Low dissolved oxygen concentration is a seasonal problem in segments of some rivers, including the Upper Snake and the main stem Willamette. Bacterial concentrations seasonally exceed desirable levels in the Yakima, Willamette, and lower Columbia and in stream reaches below a number of major communities throughout the Region. Deterioration of the biological and chemical qualities of groundwater supplies has been noted in and around some major population centers. Discharge of radioisotopes from Hanford, Washington, although in small quantities, is a matter of concern within the lower Columbia River.

PRESENT WATER RESOURCES DEVELOPMENT—1965

The approximate quantities of water withdrawn and consumed in 1965 for rural domestic, municipal, industrial, irrigation, livestock, and recreation uses are summarized in table 6–16–2.

The main instream uses of water in the Region are hydroelectric power generation, recreation, fish and wildlife habitat, waste assimilation, and navigation. These uses are essentially nonconsumptive and do not require the removal or diversion of water from its natural course. Water used to produce hydroelectric power and the water surface area used for recreation in 1965 are shown in table 6–16–3.

Navigation is generally limited to the coastal areas of Oregon and Washington, the Columbia River below Pasco, and the lower Snake and lower Willamette. The deep-water ports on the coast and the lower Columbia below Vancouver handle all types of cargo for national and international trade. The lower Columbia channel has a controlling depth of 35 feet and a width of 500 feet at a flow of 77,000 cfs. By 1971, a slack water channel with a controlling depth of 14 feet will exist on the Columbia to the head of McNary Pool and on the Snake to Lewiston, Idaho. The Willamette River, several of the larger lakes and reservoirs, and many tidal streams are used for hauling rafted logs.

Interest and participation in water-oriented recreation activities has increased rapidly throughout the Pacific Northwest. The waters and other natural assets of the Region make it one of the most important recreation and vacation areas of the Nation.

The important fish and wildlife resources of the Region require proper water temperature, quality, and flow patterns. The anadromous fish resource produces annually a sport harvest of 1,380,000 fish; a commercial harvest of 3,630,000; and a spawning escapement of 2,500,000. These estimates are actually low, because they do not include contributions to international waters, spawning escapements for some small streams, and figures for anadromous cutthroat trout. In addition, shad, striped bass, eulachon, and sturgeon landings amount to 2 million pounds annually.

Projects existing, under construction, and assured, including Canadian projects, will provide about 10,100 billion gallons (31 maf) of flood control storage. Of this storage capacity, 650 billion gallons (2 maf) will be for control of winter floods on the Willamette River, and 7,170 billion (22 maf) will be used to control spring floods on the Columbia River. A flood the size of the historical maximum flood on the Columbia would be reduced from 1,240,000 cfs to about 700,000 cfs at The Dalles.

ADEQUACY OF PRESENT DEVELOPMENT

On a regionwide basis, water supplies for municipal, industrial, and rural domestic uses are adequate. However, there are seasonal problems in some local areas, but they are usually related to system capacities rather than available supplies.

Most of the 6.6 million acres of irrigated land

TABLE 6-16-2.—*Present water use, 1965, Columbia-North Pacific Region*

(Million gallons per day)

Subregion	Rural domestic [1]	Municipal [2]	Self-supplied industrial [3]	Steam-electric power [4]	Agriculture: Irrigation [5]	Agriculture: Livestock	Other [6]	Total
				Water withdrawn				
1	17.9	131.2	102.3	4	1,417	5.2	4.0	1,682
2	8.6	40.5	12.9	—	2,586	4.2	1.0	1,653
3	14.0	34.5	8.1	—	2,138	2.8	1.5	2,199
4	11.9	44.7	57.2	—	11,368	10.5	2.0	11,514
5	12.4	38.9	78.4	—	5,296	9.4	1.5	5,437
6	4.3	25.1	109.7	—	706	5.0	1.0	851
7	2.8	56.1	166.1	—	1,666	5.5	1.5	1,898
8	0.8	17.6	330.5	—	28	1.2	1.0	379
9	32.8	181.0	515.4	4	347	4.4	3.0	1,093
10	14.1	118.2	264.3	—	234	3.4	2.5	636
11	27.7	415.4	235.9	—	154	5.0	11.5	850
12	0.9	2.1	30.0	—	445	2.1	0.1	480
Total	148	1,105	1,911	8	26,405	50	36	29,672
From:								
Groundwater	(124)	(399)	(409)	—	(3,320)	(37)	—	(4,289)
Saline	—	—	(31)	—	—	—	—	(31)
				Water consumed				
1	16.2	21.2	11.3	—	570	5.2	0.8	625
2	8.4	9.7	1.0	—	1,202	4.1	0.2	1,225
3	12.5	8.2	0.6	—	850	2.7	0.5	874
4	10.6	2.6	4.4	—	3,695	9.5	0.4	3,723
5	11.2	2.7	8.7	—	2,063	8.5	0.3	2,095
6	3.9	3.2	1.6	—	286	4.6	0.2	300
7	2.5	20.0	6.1	—	602	5.0	0.3	636
8	0.7	1.8	3.5	—	13	1.1	0.2	20
9	29.7	36.0	22.5	—	243	4.0	1.6	337
10	12.6	18.6	13.5	—	141	3.2	0.5	189
11	25.2	57.0	25.8	—	94	4.8	2.3	209
12	0.8	1.0	0.5	—	287	2.0	0.0	291
Total	134	182	100	—	10,046	55	7	10,524

[1] Water used for domestic purposes not served by public systems.
[2] Serves a population of 4,458,000 through public (both public and private ownership) systems. Includes domestic, public, commercial, and industrial uses.
[3] Water supplied by industries themselves; also includes military establishments.
[4] Public utility uses by steam-electric powerplants (predominantly for cooling).
[5] Conveyance losses not included in consumption.
[6] Recreation uses only.

are adequately supplied except during the most critically dry periods. However, at least 1 million acres, generally along smaller tributary streams, suffer perennial late-season water shortage. In many areas, achieving an adequate irrigation supply has required the use of all the natural streamflow during the summer irrigation period, as well as use of regulatory and holdover storage. Regionwide, over 100 reservoirs have individual active capacities of more than 1.63 billion gallons (5,000 af), and a total active irrigation capacity of over 5,530 billion gallons (17 maf). In addition, some 1 million acres of the total irrigated area depend all or in part upon groundwater.

Up to the present time, hydroelectric developments have been able to meet most of the Region's electric power needs. This situation is rapidly changing. The few feasible hydro sites that remain are being developed, and as needs continue to increase rapidly, more steam-electric plants will be required.

The existing channel in the Columbia River from the mouth to Vancouver, Washington, lim-

TABLE 6–16–3.—*Water used for hydroelectric power and recreation, 1965, Columbia-North Pacific Region*

Subregion	Hydroelectric power		Recreation	
	Generation	Average water use	Boating and water skiing use	Water surface used
	mil. kwh	*bgd*	*thou. visits*	*thou. ac.*
1	6,622	94.6	1,800	452
2	33,107	282.3	600	288
3	176	1.5	700	23
4	2,066	33.3	900	266
5	4,629	38.2	850	171
6	2,056	22.9	500	81
7	17,429	229.0	650	95
8	2,420	11.1	400	74
9	1,996	16.6	4,140	106
10	1,466	4.3	1,230	154
11	4,065	14.3	5,850	101
12	0	0	40	94
Total	76,032	748	17,660	1,910

its the size of vessels and commerce carried by the waterway. Deepening to 40 feet and widening to 600 feet are under way. Other navigation waterways throughout the Region are generally adequate for existing traffic.

At present, the water surface area available for recreation is generally adequate, although localized shortages may exist. Deficiencies of water surface near the larger metropolitan areas are not a serious problem at this time. Stream fisheries for resident species are generally inadequate to meet needs. Also, the quantity and quality of some streamflows are inadequate for the optimum production of anadromous fish. Water for the production of waterfowl is insufficient in some refuges and other wetland areas.

Some 60% of the 1,600 small watersheds in the Region are in need of improved management, more development, or better protection to adequately protect the water and related land resources. The agricultural land base of 158 million acres is presently producing food and fiber for both regional consumption and export. Of the present 19.5 million acres of cropland, approximately 3.4 million have a problem with excess water due to continuing wetness or flooding. More than 6.5 million acres have significant erosion problems, as do portions of the grasslands and forests.

During the floods of December 1964 and January 1965, existing projects prevented damages of $640 million; but flood damage totaling nearly $290 million did occur, indicating that additional control is needed. Additional upstream storage capacity under construction in the United States and Canada will go far toward fulfilling the objective for flood control on the Columbia River. However, floods from uncontrolled streams will still damage local areas throughout the Region.

Levels of water quality are less than desirable in some locations during certain times of the year. This is attributable to one or both of the following factors: (1) less than adequate waste reduction or treatment; (2) an insufficient quantity of water resulting from seasonal low flows, upstream consumptive uses, or regulation for power, irrigation, or other uses.

PRESENT INSTITUTIONAL AND MANAGEMENT PROBLEMS

Institutional arrangements for comprehensive river basin planning, development, and management in the Region are reasonably well suited to the current conditions and problems of water supply and use. At the regional level, there is a long history of intergovernmental study and cooperation in water and related land resources fields. Operation of the Columbia River for power is controlled by three interrelated institutional arrangements: (1) The Columbia River Treaty with Canada, (2) arrangements for use of the Pacific Northwest-Southwest transmission interconnections, and (3) the Pacific Northwest Coordination Agreement. For more than 20 years, the Columbia Basin Inter-Agency Committee carried program coordinating activities forward on a voluntary Federal-State intergovernmental basis. In 1966, the Pacific Northwest River Basins Commission was established under the Water Resources Planning Act of 1965 with broader and more definite responsibilities in comprehensive basin planning.

At the State level, water resources boards or departments, with broad responsibilities in water resources planning, development, and control have been established. All of the States are formulating cooperative State water planning programs with financial assistance under the Water Resources Planning Act. State water resources research centers or institutes are also active in each State, with financial assistance under the Water Resources Research Act of 1964. The States have prepared water quality standards under provisions of the Water Quality Act of 1965.

The new Basins Commission is expected to improve one situation in the Region which has to some extent impeded efficient planning—i.e., the often overlapping responsibilities and sometimes limited jurisdictional authority of the many Federal, State, and local government units that have been concerned, directly or indirectly, with the area's water and related land resources development.

A number of problems involving regulation, management, and water rights will arise in the course of comprehensive water planning and development. However, these do not represent serious obstacles; rather, they are matters to be routinely worked out to suit specific conditions and needs as the development program progresses. Some of the States favor a compact that would allocate the waters of the Columbia River system, but attempts to establish it have so far been unsuccessful. A general problem of importance to both the States and the Federal Government concerns the differences in viewpoint and uncertainty about water rights associated with withdrawals and reservations of Federal and Indian lands. Such uncertainty, if it persists, could hinder water and related land resources development.

Some States have a major problem in that their water laws do not recognize water use for fish and wildlife, recreation, or water quality control as beneficial. Also, certain State laws prohibit a State agency from reserving water for instream or future uses, as determined by long-range water plans. Implementation of plans including all presently authorized functions may require legal action and institutional changes at State and local levels.

PROJECTED REGIONAL ECONOMY AND WATER REQUIREMENTS

Economic projections for the Region are shown in table 6–16–4. Population is expected to mount from 1960's 5.4 million to 14.4 million

TABLE 6–16–4.—*Economic and agricultural projections, Columbia-North Pacific Region*

Item	Unit	1960 [1]	Projections		
			1980	2000	2020
Population, total	thou.	5,359	7,581	10,463	14,444
Per capita personal income	1954 dol.	2,045	3,250	4,975	7,725
Employment, total [2]	thou.	1,990	2,921	4,032	5,570
Agriculture	do.	169	114	94	91
Manufacturing	do.	447	678	904	1,198
Other commodity producing	do.	208	292	380	511
Distributive industries	do.	548	812	1,101	1,480
Service industries	do.	618	1,024	1,552	2,290
Land base	thou. ac.	169,321	169,321	169,321	169,321
Agricultural	do.	158,066	156,816	155,536	154,186
Cropland, total [3]	do.	19,468	18,739	18,587	20,138
Used for crops	do.	13,752	15,250	15,878	17,514
Idle and fallow	do.	5,716	3,489	2,709	2,624
Pasture-permanent	do.	54,101	54,249	53,806	51,627
Forest and woodland	do.	84,497	83,828	83,143	82,421
Nonagricultural	do.	11,255	12,505	13,785	15,135
Irrigated land [4,5]	do.	[6] 5,700	9,204	12,780	17,056

[1] Some data for 1959.
[2] May not check due to rounding.
[3] Includes cropland used as pasture.
[4] Includes cropland and pasture, but excludes about 6 million acres of forest lands potentially irrigable for forests.
[5] WRC projection differs (see chapter IV-4).
[6] 1965 acreage was estimated as 6,985 thousand acres.

by 2020, an increase of nearly 170%. Per capita income is expected to increase almost 280%.

Total employment is projected to increase by approximately 180%, from about 2.0 million in 1960 to 5.6 million in 2020. Employment in service industries, at present the largest sector relative to total employment, will grow from 31% of total employment in 1960 to 41% in 2020. Employment in manufacturing and in other commodity producing and distributive industries is projected to increase substantially by the year 2020, but will account for a slightly smaller percentage of total employment at that time. From 1960 to 2020, agricultural employment, in contrast to other employment sectors, is projected to decrease by 46%; however, this does not indicate a decrease in agricultural output. The number of farms is expected to decrease by half, but size of farms will increase.

The projections of major land uses reflect a continued relatively small loss of agricultural land to nonagricultural uses. From 1960 to 2020, total cropland will increase by about 3.5% and slight decreases will occur in permanent pasture and forest and woodland.

Projected water requirements for the various withdrawal and consumptive uses are shown in table 6–16–5; the total requirements for the uses (except steam-electric power) are shown by subregions in table 6–16–6. Factors considered in the projections included changes in the Region's population, income, employment, number of farms, livestock production, land use, and per capita and unit water use.

The largest consumptive use of water is irrigation. By 1965, there were about 6.6 million acres of irrigated land in the Region, an increase of nearly 2 million acres since 1944. By 2020, irrigated land is projected to be about 17 million acres, an increase of 160%. In projecting irrigation increases, consideration was given to changes in population, regional trends in needs for food and fiber, regional trends in irrigation development, availability of water,

TABLE 6–16–5.—*Projected water requirements, Columbia-North Pacific Region*

(Million gallons per day)

Type of use	Used 1965	Projected requirements 1980	2000	2020
Withdrawals				
Rural domestic	148	148	148	148
Municipal (public-supplied)	1,105	1,304	2,100	3,240
Industrial (self-supplied)	1,911	4,478	8,880	13,500
Steam-electric power:				
Fresh water	8	4,000	22,200	44,600
Saline water	0	0	19,200	52,600
Agriculture:				
Irrigation [1]	26,405	37,380	50,400	64,500
Livestock	59	77	107	147
Recreation [2]	36	60	101	158
Total	29,672	47,447	103,136	178,893
Consumptive use				
Rural domestic	134	134	134	134
Municipal	182	219	350	537
Industrial	100	244	481	738
Steam-electric power:				
Fresh water	0	13	180	630
Saline water	0	0	180	740
Agriculture:				
Irrigation [1]	10,046	15,300	21,500	28,400
Livestock	55	71	100	137
Recreation [2]	7	12	21	32
Total	10,524	15,993	22,946	31,348

[1] WRC projection differs (see chapter IV-4).
[2] Managed recreation areas.

TABLE 6–16–6.—*Projected water requirements by subregions, Columbia-North Pacific Region*

(Million gallons per day)

Subregion	Water use[1]	Withdrawals			Consumptive use		
		1980	2000	2020	1980	2000	2020
1	Irrigation	2,210	2,683	4,660	980	1,241	2,285
	Other	411	723	1,085	74	116	170
2	Irrigation	6,711	9,691	10,981	3,102	4,535	5,151
	Other	94	161	244	28	41	58
3	Irrigation	2,428	3,098	3,767	1,000	1,299	1,598
	Other	83	139	211	28	40	56
4	Irrigation	13,035	15,319	17,187	4,403	5,435	6,282
	Other	227	407	616	38	56	74
5	Irrigation	7,802	11,070	13,980	3,132	4,531	5,776
	Other	268	494	754	47	74	105
6	Irrigation	902	1,660	3,258	402	795	1,616
	Other	300	568	856	19	27	38
7	Irrigation	2,169	3,383	4,857	893	1,540	2,326
	Other	451	854	1,295	45	71	105
8	Irrigation	76	76	446	42	45	254
	Other	780	1,532	2,323	13	23	33
9	Irrigation	817	1,719	3,111	561	1,094	1,910
	Other	1,513	2,853	4,334	148	240	351
10	Irrigation	375	696	1,089	227	357	513
	Other	847	1,635	2,487	80	138	204
11	Irrigation	304	393	442	181	232	259
	Other	1,019	1,831	2,783	155	253	372
12	Irrigation	553	616	678	378	411	437
	Other	74	143	218	5	7	12
Subtotal[2]	Irrigation	37,400	50,400	64,500	15,300	21,500	28,400
Subtotal[2]	Other	6,000	11,300	17,200	700	1,100	1,600
Total[2]		43,400	61,700	81,700	16,000	22,600	30,000

[1] "Other" water use includes rural domestic, municipal, self-supplied industrial, livestock, and recreation. Requirements for steam-electric power are not included.
[2] Rounded.

and the availability of about 25 million acres of irrigable land. (No projections were made for an estimated 6 million acres of potentially irrigable forest lands.) In 1965, irrigation accounted for 95% of the consumptive use of water in the Regions; in 2020, it is projected to account for somewhat over 90%.

The transition from an essentially all-hydroelectric system to an integrated steam and hydro system is just beginning in the Region. Preliminary estimates of the electric energy loads indicate a growth from 80 billion kwh in 1966 to 183 billion by 1980, 579 billion by 2000, and 1,600 billion by 2020. Nearly all the growth in energy requirements after 1980 will be met from thermal sources. Although the generation of energy at hydroelectric plants is not expected to increase materially, the installed capacity will continue to increase. This is a result of the complementary role of hydro power for peaking purposes in an integrated system and is expected to result in hydro plant factors of 15% to 20% as compared with about 55% at present.

Detailed studies are under way concerning the locations, magnitude and number, and cooling methods of steam-electric plants. The cooling methods adopted will no doubt be a combination of cooling towers, cooling ponds, once-through flows, and other methods. Moreover, limited knowledge is available for estimating to what extent sea water will be used for cooling.

Estimated instream use for hydroelectric generation in 1980 is 1,360 bgd (1,520 maf/yr), and the figure includes reuse of water by successive plants on many streams. Subregions 1, 2, 6, and 7 account for 1,255 bgd (1,410 maf/yr) of the 1980 use, or 92%, but their use is expected to grow only slightly by 2000.

A comparison of projected recreation uses and presently available water-recreation areas within the reach of motorists indicates that water needs for recreation will continue to be concentrated in urban and urban-fringe areas. This will be particularly true in the heavily populated subregions where population pressures for open space and urban parks are becoming increasingly crucial. The broad regional and subregional availability picture may tend to mask local deficiencies that demand attention.

A number of by-products of the expected economic development of the Region will affect the instream use of fresh water by fish and wildlife. These by-products include pollution, diversion, siltation, alteration of temperatures, and inundation. The fish and wildlife values of the Region will diminish or be destroyed unless means can be found to combine water development projects with maintenance of conditions satisfactory for the production of fish and wildlife. Future instream water requirements for this use will at least equal present requirements and probably will increase.

By 2020, the Region will have to increase its output of food and fiber for its contribution toward an expected 170% increase in its population and for its proportionate share of exports. This will have to be accomplished, however, with an agricultural land base that has been reduced by 2.5%: to meet projected demands, for example, 25% more sawlogs and 3 times the present pulpwood must be produced on 2.5% less forest land, and 180% more livestock must be produced with 4.5% less grassland. This means that all land must be managed and used more intensively, and that management and development for water and erosion control must be greatly increased. About 3.4 million acres of farmland must be drained and protected from floods to permit more intensive use. To realize the desired level of flood control, some additional storage will be required for both the Columbia River system and several rivers tributary to the Pacific. Additional storage approximating 815 billion gallons (2.5 maf) will also be required by 2020 to maintain the water quality necessary for fish, municipal supply, recreation, and other beneficial uses. Any plans for storage, however, must be closely coordinated with other potential water uses to insure the realization of optimum benefits.

EMERGING WATER PROBLEMS

Future water problems of the Region will vary with location, supply, anticipated multiple uses, and magnitude of specific demands. In general, the coastal streams of Oregon and Washington and the Puget Sound area have total supplies greatly in excess of present or anticipated consumptive need; however, most of these streams have extreme seasonal variations in flow. In the interior subregions, many streams are already subject to consumptive uses that seriously deplete the flows. In fact, nearly all streams in the Region currently have at least one instream use that places demands on streamflow.

A comparison of average available water supplies with estimated withdrawals and consumptive uses by subregions for 2020 conditions is shown in table 6-16-7. It should be emphasized that the figures indicate average flows and uses without regard to seasonal variations and that the subregional totals give no indication of individual stream conditions or use. Moreover, the table does not include estimated water requirements for steam-electric power purposes.

The table indicates that withdrawals on a once-through basis will exceed average water supplies available in subregions 3, 4, 5, and 12 by 2020, and consumptive uses will deplete average available supplies in these subregions by over 70%. Such depletions will have adverse effects on such instream uses as fish and wildlife habitat, recreation, and hydroelectric power and could seriously affect water quality for both instream and withdrawal uses.

An emerging problem of increasing magnitude and concern is the higher water temperature which results from the cooling of steam-electric plants. The use of cooling towers (suggested as an alternative method) would increase the consumptive use of water and could cause atmosphere fogging, heavy condensation, and possibly a contaminated effluent.

There are substantial land and water resources available for irrigation development. However, many of the remaining developments will be costly because most underdeveloped irrigable lands lie at considerably higher elevations than the prospective water supplies and in some areas extensive water regulation facilities will be required. Water exchanges, now practiced in some irrigated areas, must be further extended; examples include the use of reservoir storage for expanded irrigated acreages in good water years in exchange for guaranteed groundwater pumping in dry years, or the substitution of groundwater pumping for natural streamflow to free the natural flows for further extension of the irrigated areas. Such exchanges will require

TABLE 6-16-7.—*Water availability, withdrawals, and consumption, 2020, Columbia-North Pacific Region*

(Billion gallons per day)

Subregion 1	Average runoff 2	Total average runoff in subregion [1] 3	Total runoff less upstream consumption 4	Withdrawal in subregion [2] 5	Consumption in subregion [2] 6	Total runoff from subregion [3] 7	Net runoff in subregion [4] 8
1	26.40	33.22	33.22	5.74	2.46	30.76	23.94
2	6.73	80.63	78.17	11.23	5.21	72.96	1.52
3	2.90	2.90	2.90	3.98	1.65	1.25	1.25
4	8.69	8.69	8.69	17.80	6.36	2.33	2.33
5	7.09	15.78	9.42	14.73	5.88	3.54	1.21
6	20.58	36.36	24.12	4.11	1.65	22.47	18.93
7	9.91	129.72	106.51	6.15	2.43	104.08	7.48
8	13.29	167.65	139.75	2.77	0.29	139.46	13.00
9	24.64	24.64	24.64	7.44	2.26	22.38	22.38
10	53.90	53.90	53.90	3.58	0.72	53.18	53.18
11	35.00	35.58	35.58	3.22	0.63	34.95	34.37
12	0.88	0.88	0.88	0.90	0.45	0.43	[5] 0.43

[1] Includes Canadian water and all other water that originates upstream.
[2] Does not include steam-electric power uses.
[3] Column 4 minus column 6.
[4] Column 2 minus column 6.
[5] Represents water discharged into water bodies from which there is no outflow.

many agreements and additional cooperation on the part of the present water users.

The anticipated growth in population and industrial activity will intensify the problems of coping with residual wastes. Improved methods of limiting the nutrient content of residual municipal, industrial, and agricultural wastes must be implemented to prevent intensification of aquatic growth problems. In subregions 3, 4, and 5, and in several individual river basins in other subregions, increases in water use may significantly reduce streamflow available for residual waste assimilation.

Larger withdrawals of water will have less effect on hydroelectric power and navigation than on other instream uses. Anticipated flows appear adequate for commercial navigation on the main waterways, which are generally confined to subregions 2, 6, 7, 8, 9, 10, and 11. However, greater amounts of waterborne general cargo and further increase in the use of super bulk carriers will create needs for additional port and shore facilities and for increased channel dimensions. In addition, currents in the Columbia River in the vicinity of Bonneville Dam and the size of the Bonneville navigation lock will restrict this potential future navigation, unless corrective measures are applied.

While the Region has excellent recreation opportunities and facilities, planners must consider the projected increased demands for water-based recreation and search for new and imaginative approaches to the problem. The problem will be particularly critical in the more populated subregions 3, 9, and 11.

The fishery resource is an instream use of water that is directly affected by nearly all other uses. Hydroelectric plants, diversions, navigation, and other nonconsumptive uses all affect fish and wildlife, as do consumptive uses and structural control measures. Despite the fact that these resources have substantial tangible values and even greater aesthetic values, the economic demands of competing water uses could destroy them if dollar evaluation should become the only directive criteria for water resource development.

To meet the future increased demands for control functions in the Region and, at the same time, protect the water and related land resources, it is imperative that the watersheds be properly managed, developed, and protected. About 60% of them require group project-type action for water conservation, flood protection, drainage, vegetative control, and other land treatment measures. In achieving this goal, the major emerging problems will center around the need to develop local interests, organization, and financial support in regard to privately owned lands.

The projected expanding population and attendant increased economic growth in the

Region especially emphasizes the need for a well-conceived and balanced program of flood control and flood plain management. If optimum use is to be made of water and related land resources, flood plain encroachment must be regulated and effective flood prevention measures must be instituted.

DEVELOPMENT AND MANAGEMENT NEEDS—1980

To attain the projected regional growth in population, industry, and agriculture, while still maintaining a desirable environment, will require improved planning and management of the Region's water and related land resources and a greatly accelerated rate of development.

Water supplies are generally adequate for rural domestic, municipal, and industrial requirements projected for 1980, but the local shortages that exist now will become more acute. Watersheds now providing municipal supplies should be managed to insure the desired quantity and quality of future water.

In the 1970's, steam-electric powerplants will be increasingly used in the Region as a primary source of power to meet base loads. The availability of water for cooling and for disposal of thermal wastes will be an important factor in locating the plants. During the same period, the capacity of hydroelectric plants will be increased to meet peaking requirements. The total installed capacity of all plants is expected to grow at an average rate of over 1 million kilowatts per year. This rate of growth will require an annual investment of over $125 million for generation capacity.

Irrigated acreage is expected to increase from 6.6 million acres in 1965 to 9.2 million by 1980, an increase of 2.6 million or 175,000 acres per year. Additional water storage of about 1,850 billion gallons (5.7 maf) will be required. This rate of irrigation development will necessitate an annual investment of about $110 million.

Flows are generally adequate for present navigation. However, extension of Columbia River navigation to Wenatchee, enlargement of the Bonneville lock and improvement of the approach channel, deepening of the lower Columbia River channel below Vancouver, and additional terminal facilities may be required by 1980.

Water-oriented recreation is rapidly expanding. Additional water surface area and an estimated annual investment of $1.5 million in facilities will be needed to meet 1980 demands. Some of the increased need for surface area could be met if reservoirs presently unavailable for recreation purposes were utilized.

An essential step in the further development of fish and wildlife as a resource is State recognition of water for this purpose as a beneficial use. Basic research is needed on many aspects of protection and enhancement, including tolerable minimum flows and water temperatures, estuarine environment, reservoir management, and passage for anadromous fish. Development should also include provisions for better access to fish and wildlife areas, as well as for pollution abatement, improved streamflow, and pond and marsh development.

Watershed protection and land management programs must be accelerated to meet the 1980 demands. Projections show that while the Region's cropland will increase only 3%, the population will increase 41% and livestock production 46%. To keep pace, watershed protection and management programs on private and public lands should be accelerated to an annual level of about $100 million.

Effective flood plain management programs must be implemented to insure best use of lands and reduce future flood damages. In addition to the United States and Canadian projects existing and under construction, the smaller multiple-purpose projects now authorized on the Snake, Grand Ronde, Rogue, and other rivers should be completed by 1980. Additional storage in the Willamette River basin is needed, as well as on many smaller streams throughout the Region.

The need for storage and treatment facilities to ensure desirable levels of water quality is widespread. Storage for this purpose can be developed in conjunction with that for other purposes.

State laws for the protection of such instream uses as fisheries and recreation must be strengthened and enforced. These laws will necessarily deal with quality control, which is important in differing degrees to all water uses.

A type 1 framework study is well under way in the Region under the leadership of the Pacific Northwest River Basins Commission. This study will provide broad strategies for meeting the Region's water and related land resources development and management needs.

Columbia-North Pacific Region
Comprehensive Framework Study

Prepared by
Columbia-North Pacific Technical Staff
Pacific Northwest River Basins Commission
Vancouver, Washington

Table 133 - Areas by State and County, Subregion 6, 1967

State and County	Water Area Sq. Mi.	Water Area Acres	Land Area 1/ Sq. Mi.	Land Area 1/ Acres	Total Area Sq. Mi.	Total Area Acres
Idaho						
Adams	01.8	1,100	421.5	269,800	423.3	270,900
Benewah	.0	0	23.3	14,900	23.3	14,900
Blaine	06.0	3,900	127.4	81,500	133.4	85,400
Boise	.0	0	01.9	1,200	01.9	1,200
Clearwater	00.8	500	2,510.4	1,606,600	2,511.2	1,607,100
Custer	06.4	4,100	3,570.0	2,284,800	3,576.4	2,288,900
Idaho	05.9	3,800	8,516.1	5,450,300	8,522.0	5,454,100
Latah	.0	0	1,061.6	679,400	1,061.6	679,400
Lemhi	00.6	400	4,193.0	2,683,500	4,193.6	2,683,900
Lewis	02.4	1,500	475.6	304,400	478.0	305,900
Nez Perce	10.3	6,600	843.7	540,000	854.0	546,600
Shoshone	.0	0	381.3	244,100	381.3	244,100
Valley	06.0	3,800	2,396.5	1,533,800	2,402.5	1,537,600
Total Idaho	40.2	25,700	24,522.3	15,694,300	24,562.5	15,720,000
Oregon						
Baker	00.4	300	08.0	5,100	08.4	5,400
Umatilla	00.4	300	50.0	32,000	50.4	32,300
Union	01.6	1,000	1,745.0	1,116,800	1,746.6	1,117,800
Wallowa	02.9	1,800	3,147.3	2,014,300	3,150.2	2,016,100
Total Oregon	05.3	3,400	4,950.3	3,168,200	4,955.6	3,171,600
Washington						
Adams	05.8	3,700	501.5	321,000	507.3	324,700
Asotin	03.6	2,300	633.4	405,400	637.0	407,700
Columbia	03.4	2,200	459.6	294,100	463.0	296,300
Franklin	11.4	7,300	310.0	198,400	321.4	205,700
Garfield	04.2	2,700	712.8	456,200	717.0	458,900
Lincoln	00.5	300	108.1	69,200	108.6	69,500
Spokane	04.7	3,000	365.8	234,100	370.5	237,10
Walla Walla	32.3	20,700	249.1	159,400	281.4	180,10
Whitman	14.3	9,200	2,142.1	1,370,900	2,156.4	1,380,10
Total Washington	80.2	51,400	5,482.4	3,508,700	5,562.6	3,560,1
Total Subregion	125.7	80,500	34,955.0	22,371,200	35,080.7	22,451,7

1/ The term "land" is defined to include all water bodies under 40 acres and streams under one-eighth mile in width.
Source: U.S.D.A. Conservation Needs Inventory adjusted to the U.S. Census.

Subregion	1900	1910	1920	1930	1940	1950	1960	1965	1980	2000	2020
						(Thousands)					
1	180.2	326.1	361.8	378.0	417.4	489.4	563.7	595.1	699.1	897.1	1,140.4
2	45.9	109.6	112.6	112.0	130.1	157.4	193.6	198.6	253.0	334.0	431.3
3	23.2	68.2	92.4	106.5	131.3	209.3	227.6	236.7	280.7	355.2	443.7
4	45.6	109.0	184.4	187.8	217.8	242.5	277.2	302.0	350.9	450.5	576.0
5	56.0	106.3	130.9	136.4	178.3	215.3	252.4	268.2	328.7	430.4	553.5
6	96.1	131.7	132.8	130.3	137.3	148.9	156.0	163.3	193.5	234.6	274.3
7	86.6	123.5	128.8	130.1	143.2	184.9	198.7	210.5	251.4	321.9	404.4
8	47.2	87.6	101.2	139.1	161.3	214.0	224.5	240.1	277.9	349.4	441.3
9	233.3	416.4	496.3	609.9	691.2	992.4	1,168.9	1,338.9	1,727.3	2,397.6	3,237.2
10	89.9	151.1	172.2	215.8	235.6	328.8	381.4	405.5	465.5	575.4	708.9
11	264.5	607.2	772.5	909.9	1,007.1	1,418.4	1,768.1	1,904.1	2,449.7	3,345.3	4,448.1
12	5.4	8.7	8.0	10.8	11.7	12.8	13.9	13.3	16.3	18.7	21.3
G-NP	1,174.0	2,245.3	2,693.9	3,066.4	3,462.3	4,614.0	5,426.1	5,876.1	7,293.9	9,710.1	12,680.3
						(Millions)					
U.S.	76.1	92.4	106.5	123.2	132.2	151.3	179.3	194.0	234.2	306.8	397.6

Table 87 - Projected Population, Subregion 6 1/

	1980	2000	2020
		(Thousands)	
Salmon Subbasin	13.0	15.0	16.5
Municipal	5.1	6.2	7.0
Rural	7.9	8.8	9.5
Clearwater Subbasin	86.8	115.6	147.1
Lewiston Service Area	54.8	82.0	112.6
Municipal	46.8	78.0	112.6
Rural	8.0	4.0	-
Other	32.0	33.6	34.5
Municipal	14.8	16.6	18.6
Rural	17.2	17.0	15.9
Subtotal	86.8	115.6	147.1
Municipal	61.6	94.6	131.2
Rural	25.2	21.0	15.9
Lower Snake and Other Tributaries	93.7	104.0	110.7
Pullman Service Area	30.5	38.0	43.4
Municipal	29.8	38.0	43.4
Rural	0.7	-	-
Other	63.2	66.0	67.3
Municipal	26.7	30.0	32.6
Rural	36.5	36.0	34.7
Subtotal	93.7	104.0	110.7
Municipal	56.5	68.0	76.0
Rural	37.2	36.0	34.7
Total Subregion	193.5	234.6	274.3
Municipal	123.2	168.8	214.2
Rural	70.3	65.8	60.1

APPENDIX

PART 4

WATERPOWER RESOURCES OF IDAHO

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

CONSERVATION DIVISION

WATERPOWER RESOURCES OF IDAHO

By: L. L Young and J. L. Colbert

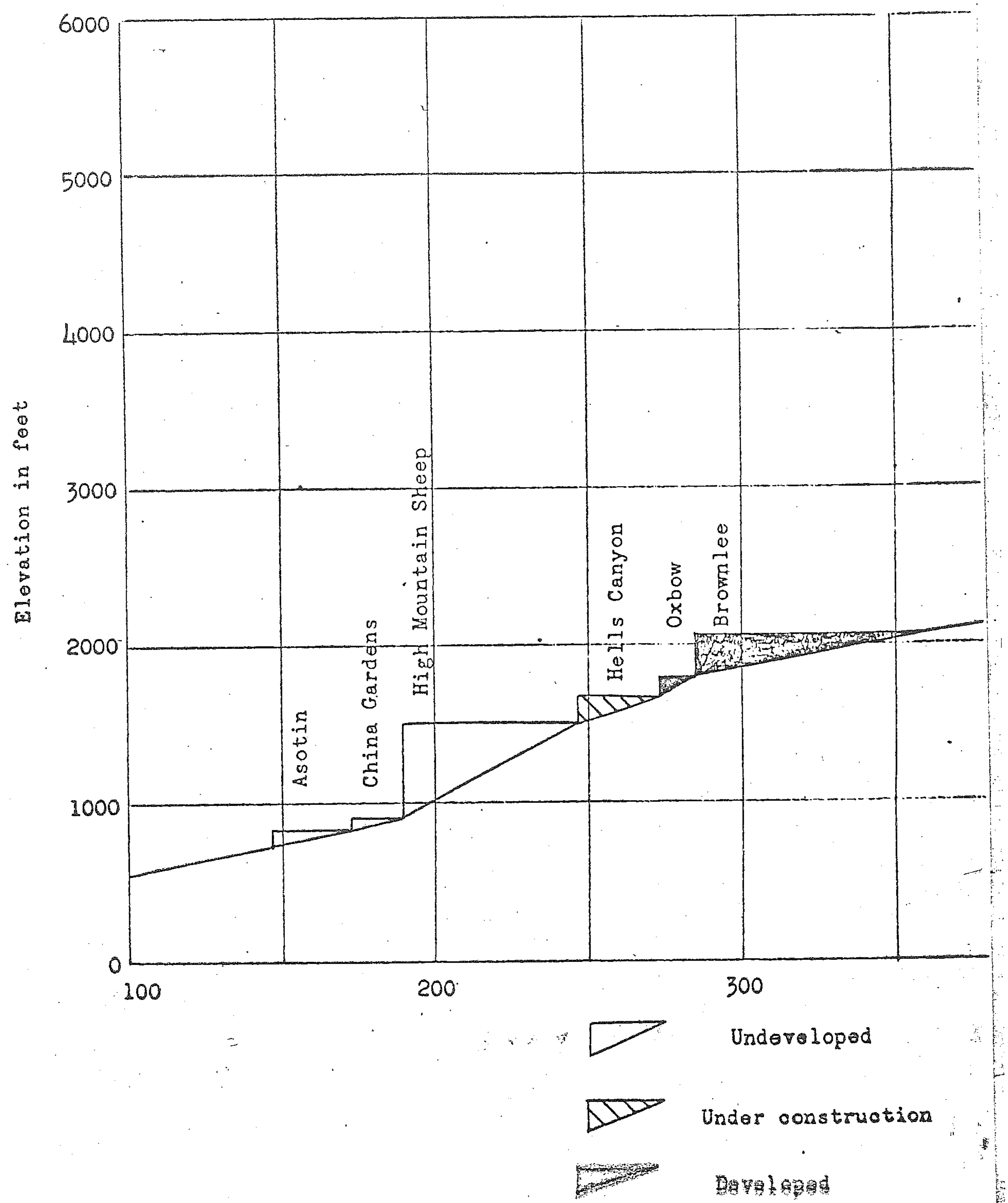
Snake River basin

The Snake River basin comprises about 108,500 square miles of mountains, foothills, and plains in the States of Wyoming, Idaho, Utah, Nevada, Oregon, and Washington. The river is more than 1,000 miles long and more than half of its length is in canyons. In Idaho the drainage area is about 72,700 square miles and the length of river channel is about 775 miles. The reach of river across Idaho between the Idaho-Wyoming and Idaho-Oregon boundaries flows alternately in deep narrow gorges and broad valleys where only shallow channels guide it. These combinations make practically complete utilization for irrigation possible without serious impairement to waterpower values. Continual increasing use of water for irrigation in southeastern Idaho appears to be increasing the low-water flow at points below King Hill. Forty-two reservoirs with a capacity of 5,000 acre-feet or more have been constructed in the Snake River basin within Idaho. Many of these reservoirs store water for irrigation only but an increasing number of them are being designed for other purposes too. Power and flood control features are now usually added to irrigation benefits and some reservoirs are built for power only.

In point of drainage area the Snake River is one of the larger rivers of the United States being exceeded, in the order named, only by the Missouri, Columbia excluding Snake River, Rio Grande, Colorado, Ohio, Arkansas, and the Mississippi above the Missouri. In point of mean flow the Snake exceeds the Arkansas, Colorado, and Rio Grande Rivers of those named above.

The river has its source on Two Ocean Plateau on the western slope of the Continental Divide near the northeast corner of Yellowstone National Park, Wyoming. According to the Two Ocean pass 1:62,500-scale topographic quadrangle map the main river is a perennial stream at an altitude of over 9,700 feet above sea level and the small lake at the head of tributary Plateau Creek is more than 10,000 feet in altitude. There are many small lakes on the plateau at altitudes greater than 9,000 feet, and Mariposa Lake on a tributary of Plateau Creek has a surface area of about 30 acres and lies at an altitude of

FIGURE 5.--PROFILE OF SNAKE RIVER SHOWING DEVELOPED AND UNDEVELOPED POWERSITES.



The river flows generally southwestward through Wyoming to the Idaho-Wyoming line near the mouths of the Grays and Salt Rivers. After entering Idaho it flows northwestward to the mouth of Henrys Fork, a distance of about 80 miles. In this reach the river has eroded a rather wide canyon in lava flows and has formed some exceptionally beautiful valleys notably Swan and Conant Valleys. Swan Valley is cultivated for hay raising but diversification to grain and potatoes is evident. The river passes through alternate valleys and canyon sections where the principal activity appears to be stock raising.

Some interesting prehistory is found in the Portneuf Basin. Its tributary, Marsh Creek, on one occasion at least, carried water from ancient Lake Bonneville to the Snake-Columbia system.

Lake Bonneville, believed to be contemporaneous with Wisconsin glaciation, formed its highest major terrace (The Bonneville Terrace) at an altitude of about 1,000 feet above the present level of Great Salt Lake. This terrace is evidence that the lake was at that stage for a long period then overflowed the basin rim into the Snake River by way of Marsh Creek at Red Rock Pass. Marsh Creek continued to drain the huge lake until it had fallen at least 400 feet below the Bonneville Terrace level and about 600 feet above the surface of the present Great Salt Lake. At this stage a resistant limestone retarded the cutting action of the stream and the lake became stable again. Remaining at the new altitude for a long period the lake formed the Provo Terrace (Pack, 1939). The Bonneville and the Provo are the most prominent terraces left by the ancient lake and can be identified almost anywhere along the old shore lines.

Downstream from the Weiser and Burnt Rivers the Snake has cut its largest and deepest canyon, Hells Canyon, which becomes progressively deeper and rugged until it passes the Seven Devils Mountains area about 40 miles north of Weiser. In the remaining distance to Clarkston the canyon decreases in depth but not in ruggedness.

He-Devil Mountain, 5.4 air miles from the river, rises 9,393 feet above sea level, and on the Oregon side along Summit Ridge, Black Mountain, only two miles away, reaches an altitude of 6,862 feet. The river surface is about 1,360 feet above sea level making the canyon more than 8,000 feet deep on the Idaho bank and 5,500 feet deep on the Oregon side. Near the Hells Canyon damsite, Cliff Mountain, Idaho, is 7,384 feet above sea level and Barton Heights, Oregon, 3.6 miles away, is 5,743 feet in altitude. Hells Canyon dam now under construction in sec. 15, T. 22 N., R. 3 W., will be 320 feet high and only 994 feet long at the crest. The 500-foot dam originally planned for this site was to have been only 1,600 feet long at the crest. The canyon continues deep and wild as the river proceeds northward, and is still more than a mile deep between Dry Diggins Ridge (7,606 feet) and Hat Point, Oregon, 6,982 feet. The river is flowing at an altitude of 1,300 feet in this reach. The Powder, Imnaha, Salmon, and Grande Ronde Rivers join the Snake in this canyon without forming valleys of any appreciable size and the river is flowing in a canyon 4,000 feet deep downstream from the mouth of the Salmon River. North of the mouth of the Grande Ronde River the canyon depth and ruggedness moderates but is still 300 feet deep near the towns of Lewiston, Idaho, and Clarkston, Washington. A fair-sized valley has been formed at the mouth of the Clearwater River and a large area of tableland south of the Clearwater River indicates that the two streams occupied a larger valley in ancient times.

feet deep in places. At the Idaho-Wyoming boundary line the water surface of the river reaches an altitude of 5,620 feet above sea level in the Palisades Reservoir when it is full. At Clarkston on the Idaho-Washington boundary line the water surface of the river is about 715 feet. The total fall across the State is 4,905 feet in 780 miles, or about 6.3 feet per mile.

With the exception of the Anderson Ranch Powerplant on the South Fork Boise River (installed capacity 27 MW), all developed waterpower plants in Idaho with a capacity of more than 10,000 kilowatts are on or near the main stem of the Snake River. The early plants were small and used only part of the water flowing past them, whereas the modern ones have storage reservoirs and utilize all of the flow. The early plants include Swan Falls (1901), Shoshone Falls (1901-07), Oxbow (1908-14), and Thousand Springs (1912). The new larger plants are C. J. Strike (1952), Palisades (1957), Brownlee (1958), and Oxbow (1961). A number of reaches of the river in the section between the Idaho-Wyoming, and Idaho-Oregon boundary lines remain undeveloped. The completed Brownlee and Oxbow dams and powerplants together with the Hells Canyon project now under construction and the High Mountain Sheep project, recently approved for a Federal Power Commission license, will almost complete the development of the reach of river forming the Idaho-Oregon boundary line. This is the section of the Snake River having the greatest waterpower potential per mile. The reach is 142 miles long and falls 1,162 feet (from altitude 2,077 feet at the Brownlee backwater limit near Weiser, Idaho, to altitude 915 feet at the tailwater of the proposed High Mountain Sheep dam near the mouth of the Salmon River). This reach of river has an average capacity of 1,540 kw per foot of fall.

Salmon River basin has the largest gross theoretical power potential of all Snake River tributaries and has the greatest potential of any single river in the State, exceeding even that of the Snake River. The Clearwater Basin is next and is followed, but not closely, by the Payette and Boise Basins.

The <u>Granite Creek site</u> (13-2902+30) assumes the accumulation at a powerhouse site in sec. 26, T. 23 N., R. 3 W., of the runoff from 22 square miles of Granite Creek and its principal tributaries all draining the west side of Seven Devils Mountains, including 9,393-foot-high He Devil Peak. The diversions would be at an altitude of 4,400 feet and about eight miles of conduit, including a one-mile-long penstock, a one-mile inverted siphon, and several short tunnels. The tailrace would be at altitude 1,510 feet, the maximum pool elevation authorized for the High Mountain Sheep project.

The <u>Old Timer site</u> (13-2902+40) would divert Sheep Creek at an altitude of 3,800 feet near Old Timer Creek in sec. 13, T. 24 N., R. 2 W., where the drainage area is 20 square miles. A three-mile-long conduit, which might be shortened somewhat by tunneling, and a one-mile penstock would reach the powerhouse site in sec. 8 of the same township on the Snake River at the backwater altitude of High Mountain Sheep Reservoir, 1,510 feet. Appendix, Rock Island, Gem, Sheep, and Shelf Lakes in the headwaters of West Fork Sheep Creek should have an equalizing effect upon the discharge available during the dry season.

The High Mountain Sheep Dam (13-2920+30) at mile 188.9, sec. 14, T. 29 N., R. 4 W., Boise Meridian, Idaho, sec. 11, T. 4 N., R. 48 E., Willamette Meridian, Oregon, was recently authorized to Pacific Northwest Power Company under an application for Federal Power Project No. 2243. The dam will be a concrete arch with a structural height of 670 feet and will form a reservoir capable of storing 3,600,000 acre-feet of water. Two outdoor powerhouses, one on each side of the river, will have a combined capacity of 1,750 MW. Water will be raised to the Hells Canyon tailrace (1,510 feet) some 58 miles upstream from the damsite. The High Mountain Sheep tailrace is 915 feet.

The High Mountain Sheep damsite is on the Snake River eight-tenths of a mile upstream from the mouth of the Salmon River. This site has been selected over an alternative, the Nez Perce project, in which the dam would have been constructed downstream from the mouth of the Salmon River. The problem of getting anadromous fish, now spawning in the Salmon River, over Nez Perce dam was a principal factor in deciding in favor of High Mountain Sheep which can be built now. Nez Perce dam would also have been an arch with a structural height of 715 feet. It would have stored 6,600,000 acre-feet of water, about twice as much as the High Mountain Sheep reservoir, and 3,200 MW of generating equipment was planned for its powerhouse, also nearly twice as much as High Mountain Sheep. Depending upon a satisfactory solution to the fish-passage problem the undeveloped portion of the Nez Perce reservoir site probably will be utilized by constructing a dam at the Lower Canyon site on the Salmon River immediately upstream from its mouth.

Salmon River

If you will place a sheet of tracing paper over a small-scale map of the State of Idaho, trace the course of the main stem of the Salmon River from its headwaters to its mouth, lift your pencil and draw a small circle over the Snake River between that point and the mouth of the Grande Ronde River, lift your tracing paper by its lower right-hand corner and look through it from the reverse side, you may note that you have made a squiggle that resembles a large question mark. The past history of the Salmon River is well known. Its future is an unknown like the squiggle. The native Indians described it to the Lewis and Clark party as the "river of no return". This probably meant that one attempting to go down the river would never return for the reason that he would never reach his downstream destination, or could never get back. To several important species of anadromous fish, however, the Salmon River has been the river of return and it has become known as the most productive spawning area in the conterminous States for these fishes.

The basin has at times made important contributions to the mineral wealth of Idaho and has always been a valuable livestock producing area, being favorably endowed for both cattle and sheep raising. The higher lands are suited to grazing only, but there are level valleys abundant hay and grain under irrigation. In recent years the area has gained popularity throughout the Nation as a wilderness area and an ever increasing number of persons seeking solitude and relaxation close to nature visit the basin.

The Salmon River has a potential value for waterpower production greater than any other river in Idaho, possessing one-third of the gross theoretical potential waterpower of the State of Idaho. A reservoir site near the settlement of Stanley has the capability of regulating the stream to a continuous discharge of 660 cfs--91 percent of average discharge at the site. The average surface altitude of this reservoir would be about 6,400 feet above sea level. Potential powersites on the Salmon River and potential and developed sites on the Snake and Columbia Rivers make most of this head developable. The gross theoretical potential power of the 660 cfs equated to sea level is 359 MW. Storage sites downstream could maintain this controlled flow to average flow ratio of 91 percent. The gross theoretical waterpower of the Salmon River basin equated to sea level is about 3,800 MW, of which 3,000 MW of this is developable inside the State of Idaho and the remainder on the Snake and Columbia Rivers downstream from the mouth of the Salmon River.

Gross theoretical power is computed for gross head and 100 percent efficiency. After reducing gross head to effective head and by further reducing this by the efficiency of the turbines and generators, an overall efficiency of 70 percent might be achieved. Applying this to the 3,000 MW available in Idaho, a continuous capacity of 2,100 MW of firm power could be made available at plants in the Salmon River basin. To allow for appropriate daily and seasonal variations in demand, the plants probably would have a total installed capacity of at least 4,000 MW.

It would be fortunate for all concerned if fish life, recreation, livestock production, minerals, and waterpower values could be utilized concurrently and perpetuated to the fullest. The Salmon River basin offers a locale for a test of the sincerity and reasonableness of all parties concerned in the various values present and it may well be that the final solution will provide for a very high realization of each basin-wide multiple use.

The Salmon River basin includes about 14,000 square miles of the central part of Idaho. The basin is generally rough, mountainous, forested, and sparsely settled. Its principle character is a high and rugged mountain mass, its southern border dominated by the Sawtooth Range. The principle headwaters of the main stem originate in these Sawtooth mountains and the river flows northeastward until turned north and finally west by the Bitterroot Range on the east and Clearwater Range on the north. The Seven Devils Mountains divide the Salmon Basin from the Snake River on the west. While flowing northeasterly a distance of about 150 miles, the Salmon River is joined by its tributaries Yankee Fork, East Fork, Pahsimeroi, and Lemhi Rivers. In an additional distance of about 150 miles, while flowing north, northwest, and west, the river is joined by North Fork, Middle Fork, South Fork, and Little Salmon Rivers. At the mouth of the Little Salmon River, the Salmon turns sharply northward to follow a continuing narrow valley for another 40 miles, then swings west to enter the Snake River near the lower end of the Middle Snake River canyon. Figure 9 is a longitudinal profile showing main stem powersites and figure 10 is a planimetric map of the basin showing all of the powersites used to determine the potential power of the basin.

FIGURE 9.--PROFILE OF SALMON RIVER SHOWING UNDEVELOPED POWERSITES ON MAIN STEM